# The SUDARE/VOICE INAF VST GT Survey

# Galaxy Evolution, AGN Variability and Supernova Host Galaxies with VST


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**ESO Surveys Workshop - 15-18 Oct 2012**

# The SUDARE/VOICE INAF VST GT Survey
# The Deaths of Stars & The Lives of Galaxies

- A Supernova Search Survey (SUDARE) and a Medium-Deep Extragalactic Imaging Survey (VOICE) long identified as projects to be pursued within the INAF VST GT Program
- In 2009 SUDARE and VOICE proposed as separate projects
  - SUDARE wanted access to well-known extragalactic fields and would provide substantial amounts of imaging data at sub-arcsec resolution
  - VOICE to observe where optical imaging of deep Spitzer/ VISTA fields was still shallow and to fill in where SUDARE-only imaging depth would not be satisfactory (CDFS/ES1)
- In 2010 SUDARE and VOICE merged to maximize science output of INAF VST GT and multi-wavelength synergies
- SUDARE observations have been going on for ~ a year

# Extended CDFS Field

## Extant Optical Data

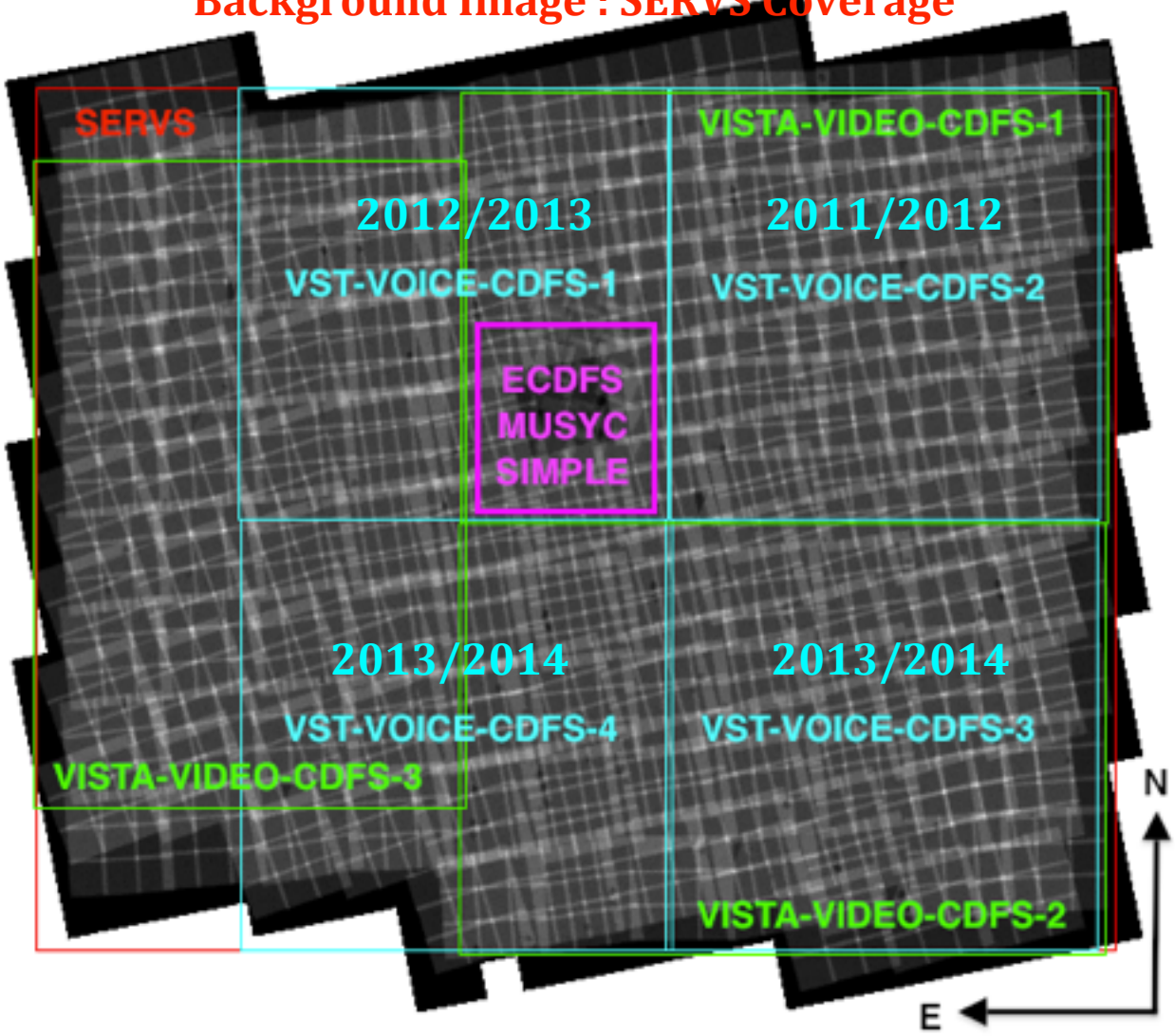
MUYSC 32-band imaging
to 26 (AB) over 0.25 deg$^2$

SWIRE ugri imaging
to 24 (AB) over 4 deg$^2$

## Observing Plan

Piggy-Backing on SUDARE
for 2011/2012 & 2012/2013

VOICE Ramping Up
from 2013/2014 onwards



# Extended ES1 Field

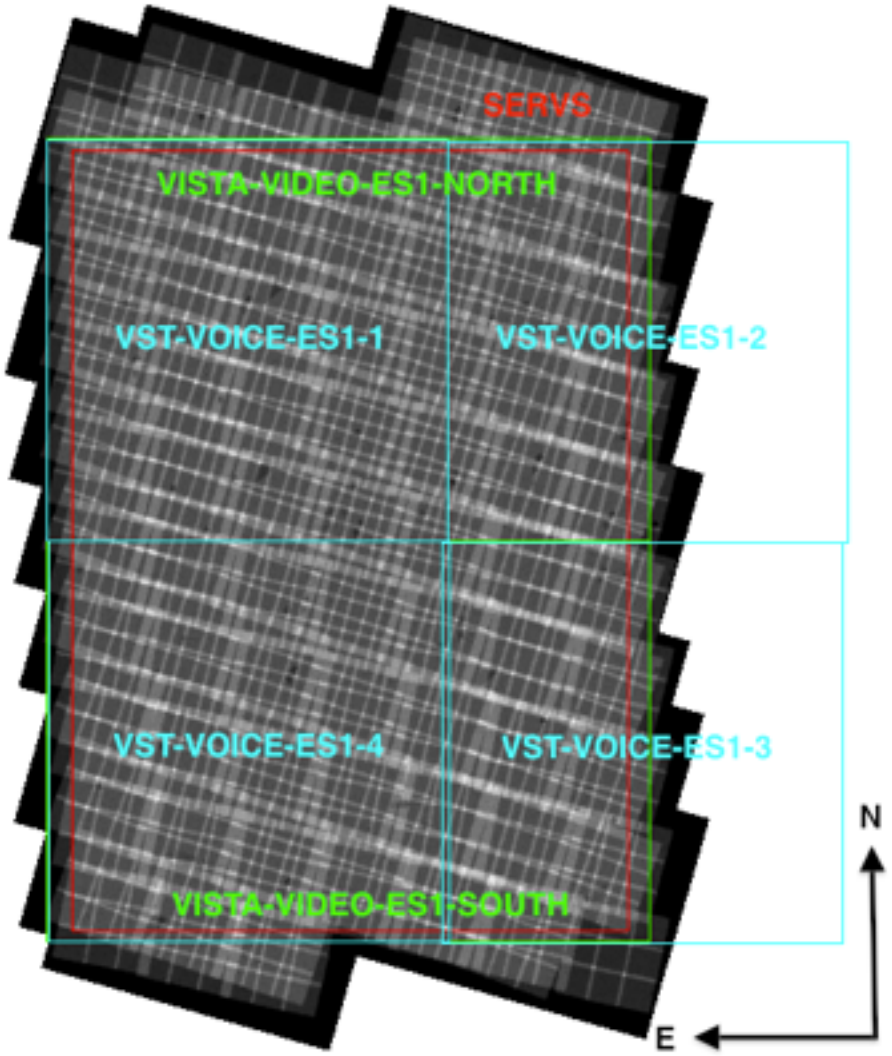
## Extant Optical Data

**ESIS BVRI imaging**
**to 24.5 (AB) over 4 deg$^2$**

## Observing Plan

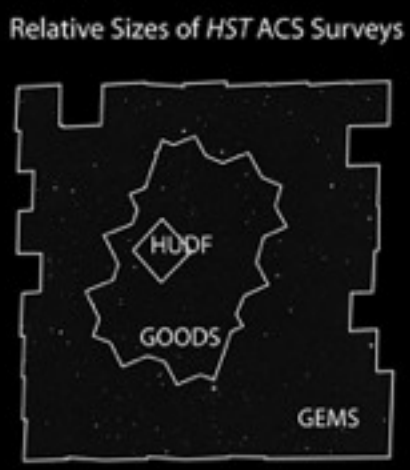
**TBC**
**After Survey Review in 2014**

**Background Image : SERVS Coverage**

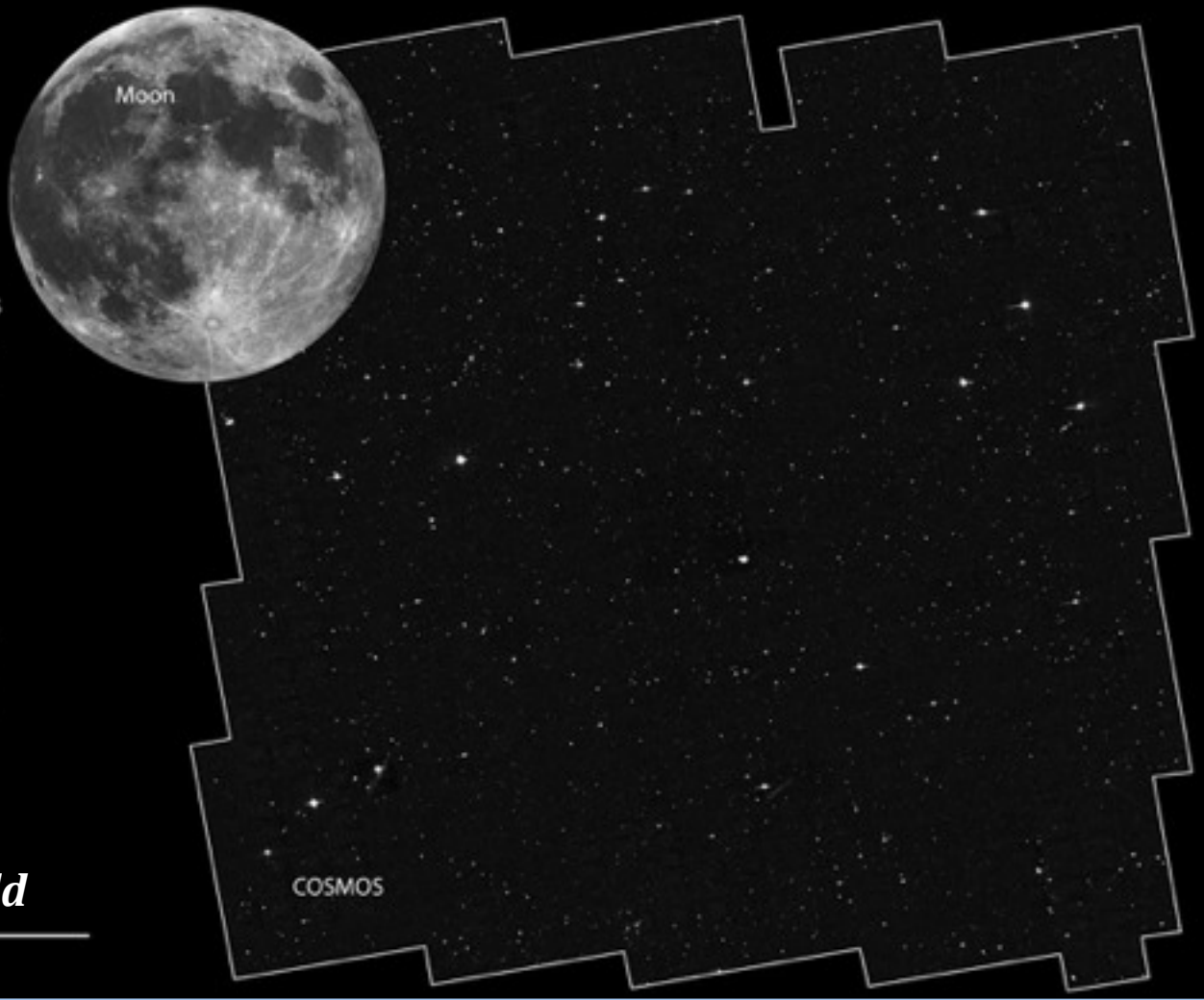


# COSMOS Field

*"It will be like being on the Moon and being able to recognize buildings in New York and trucks on Broadway"*
*Nick Scoville, 2003*



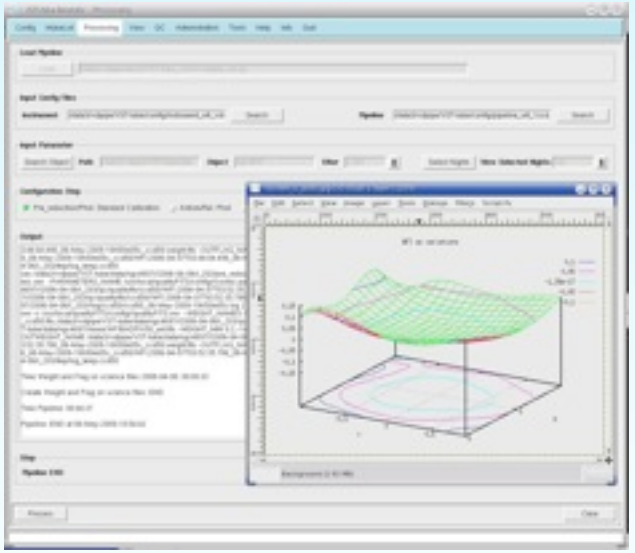

*SUDARE Extension in Chilean Time*
*NB : UltraVISTA Field*

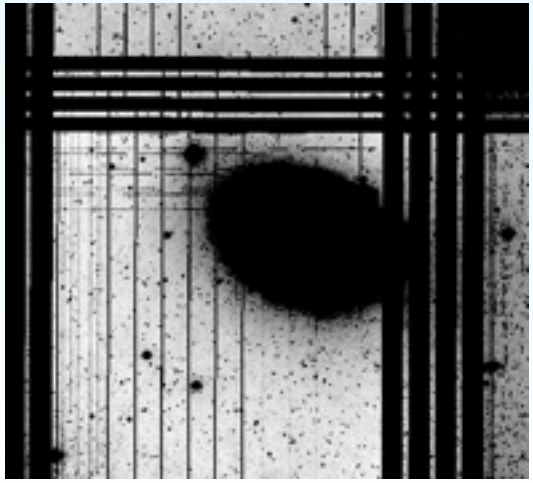


# VstTube

Pipeline Developed in Naples by **Grado & Limatola**

- *From raw to fully calibrated images (multi-instrument support)*
- *Tailored on surveys needs*
- *GUI to facilitate processing and administration*
- *Includes a growing set of analysis tools*
- *Supported surveys: VEGAS, ACCESS, SUDARE, VOICE, STEP, STREGA, COSMOS (Chilean GTO)*



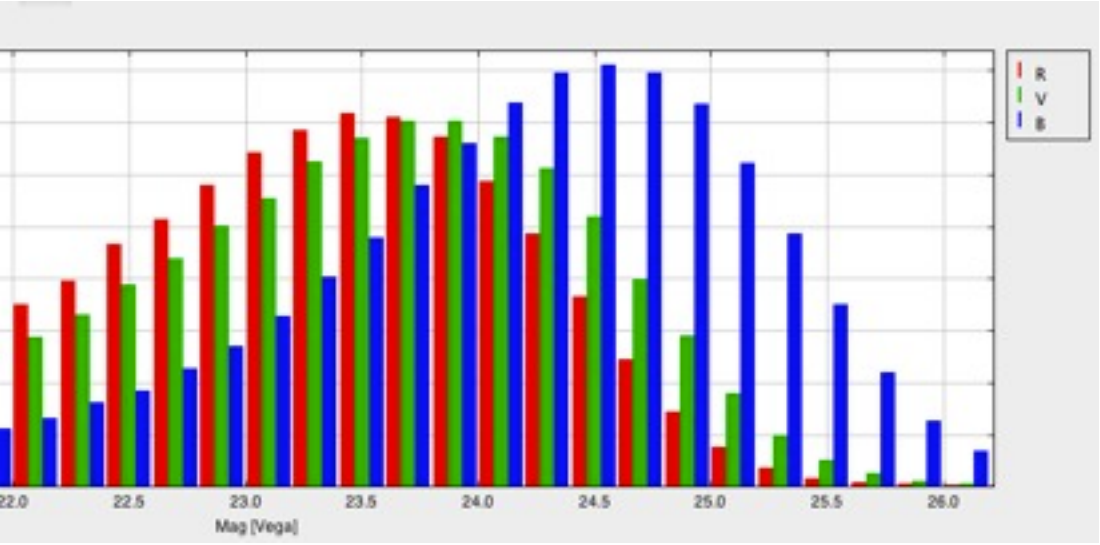


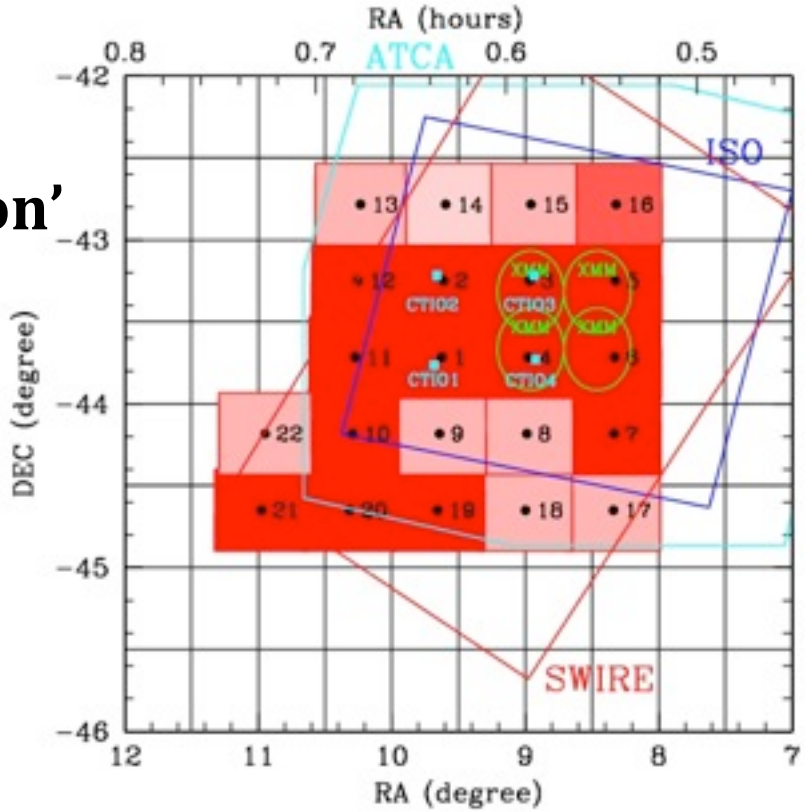
True noise map propagation
NGC4697 Weight map section

# VST-Tube ESIS Data Reduction

**ESIS WFI BVR Imaging Data over 4.5 deg^2**
**ESO Large Program (PI : Franceschini, Observed 2001-2006)**
**http://www.astro.unipd.it/esis**

**Completing ESIS Data Reduction**
**Prototyping VOICE Data Reduction**
**Integration within Spitzer 'Data Fusion'**



# VST Data Reduction Challenges

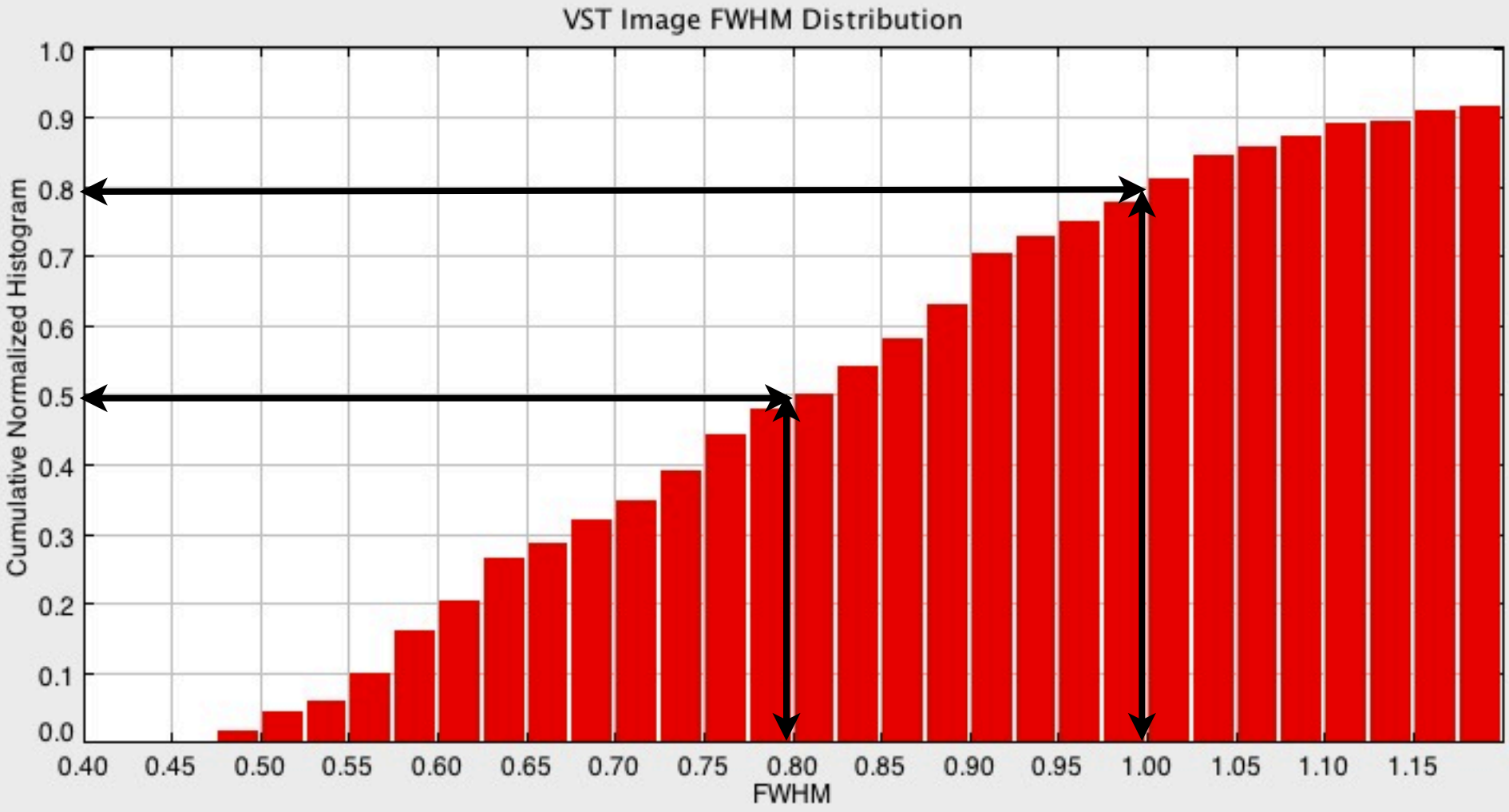
Data Reduction currently driven by SN search needs

Single Epochs as well as Deep Stacks (Reference Images) routinely produced

Still early days, but learning from other VST GT projects as well as KIDS-ATLAS

CDFS-2 gri Three-Color Image

# VST Image FWHM Distribution



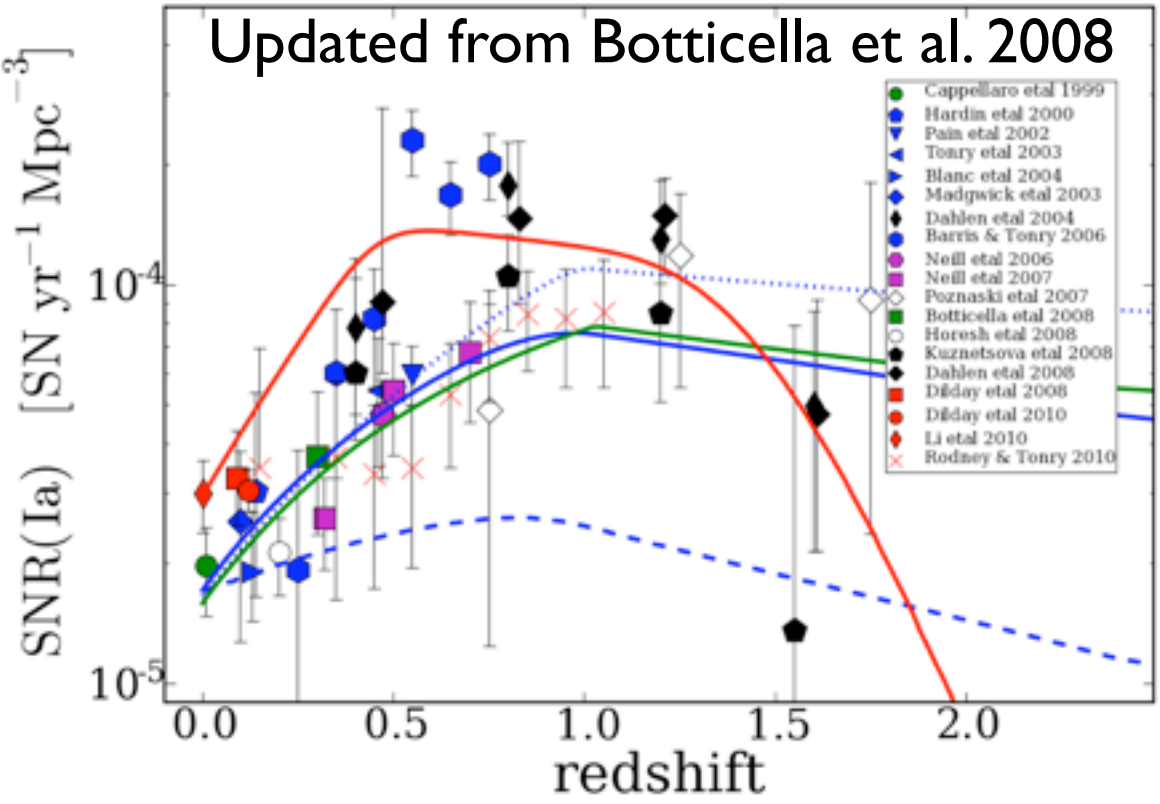

**Can achieve sub-arcsec resolution ~80% of the time**

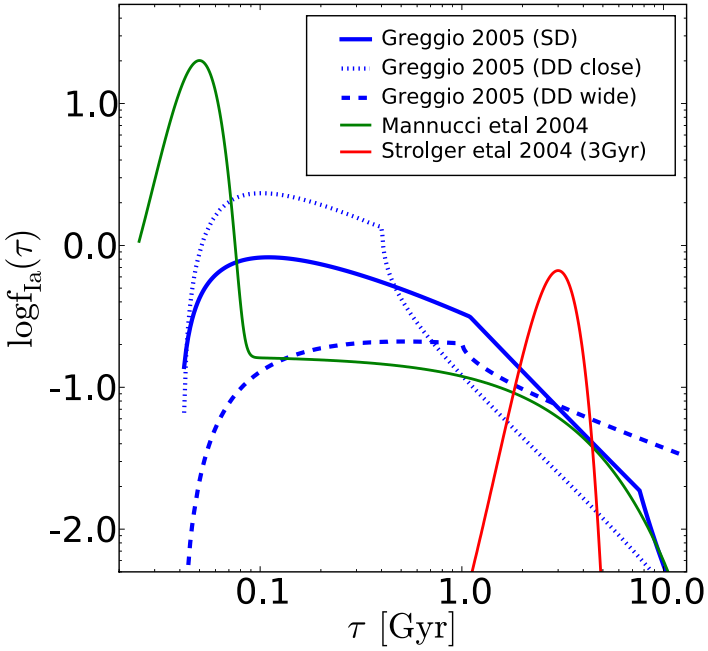
# Supernova diversity and rate evolution
# SUDARE - Cappellaro/Pignata

## Why SN rates?

- Link progenitor and stellar evolution scenarios
- Probe star formation history and nucleosynthesis
- Test scenarios for compact objects formation (NS and BH) or extreme events (GRB)
- Support search programs for neutrinos & GW

# SNIa Rate Evolution




Measuring SNIa Rates & Confronting SN DTD Models

# Supernova diversity and rate evolution
# SUDARE

Fields : CDFS 03 32 13 -27 50 00 (PI : Cappellaro - INAF GT)
COSMOS 10 00 28 +02 12 21 (PI : Pignata - Chilean Time)

r-band exposure every 3 day
g,i band colors once 10 days

Synergy with VOICE by Covone, Vaccari et al.

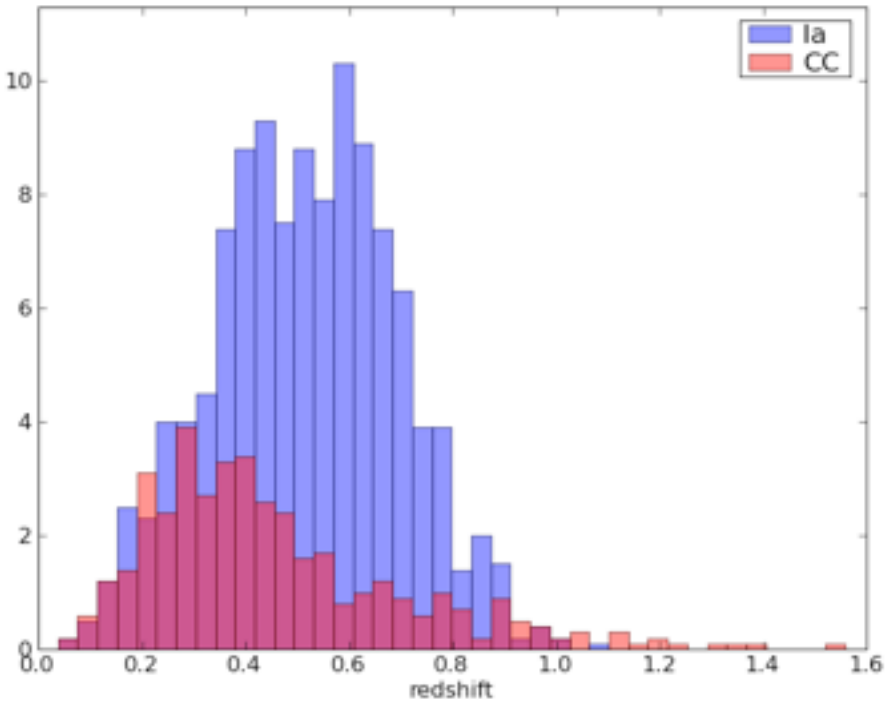
| | x field & x year | x field & x year |
|---|---|---|
| Search run | 45 hr | exposures : 30/45 min (dark/gray) |
| Color photometry | 25 hr | epochs : (up to) 60 in r and 15 in gi |
| | | single epoch mag limit of 24(.5) AB |

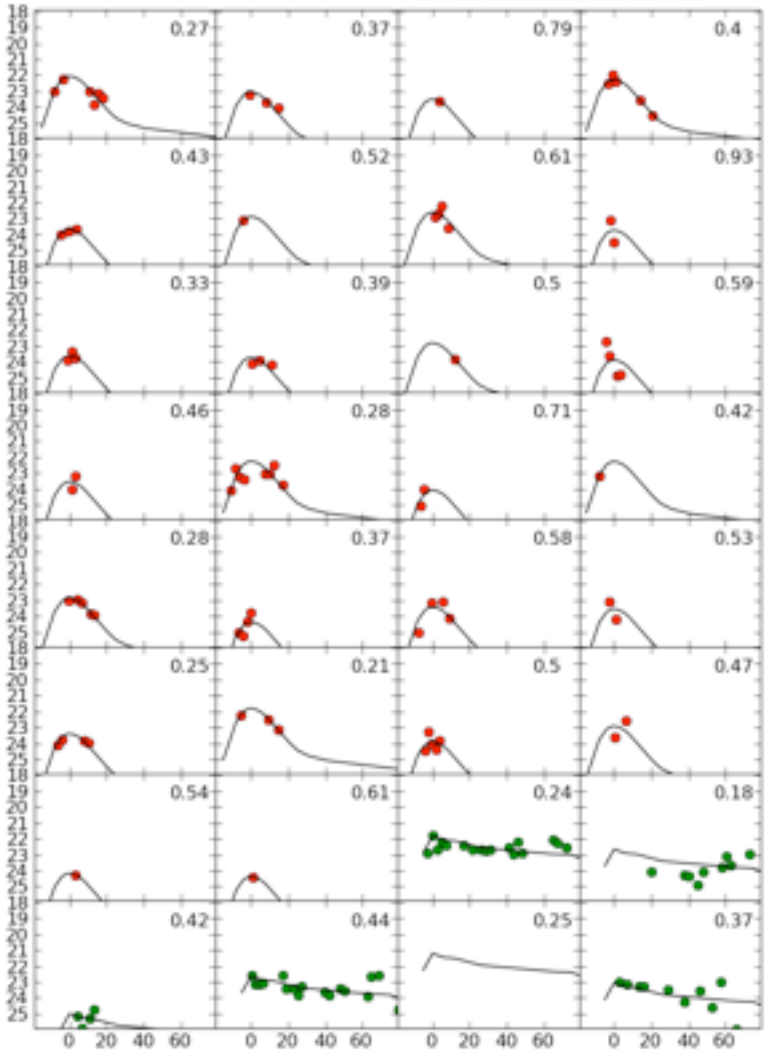
Time request : 70 hr / yr / field

# SN Search Simulatic

dx : e' una simulazione della distribuzione col redshift degli eventi aspettati dalla search (date mag limite, frequenza di osservazione,etc)

Expected Detections
50 SNe / field / season
(200-300 in 4 years)



# SN Search Process

• All new epochs are compared against two different references.
For the image difference with psf match we use Andrew Becker's ***hotpants*** (http://www.astro.washington.edu/users/becker/hotpants.html)

• Variable objects are searched with ***sextractor***. Source are assigned a score based on different measured parameters (eg. FWHM, flux radius, distance from saturated stars, etc.)

• The candidate catalog (typically containing a thousand objects) is cross-matched (using ***stilts***) with a reference catalog of sources (derived from a stacked deep image) and with archival SWIRE optical catalogs

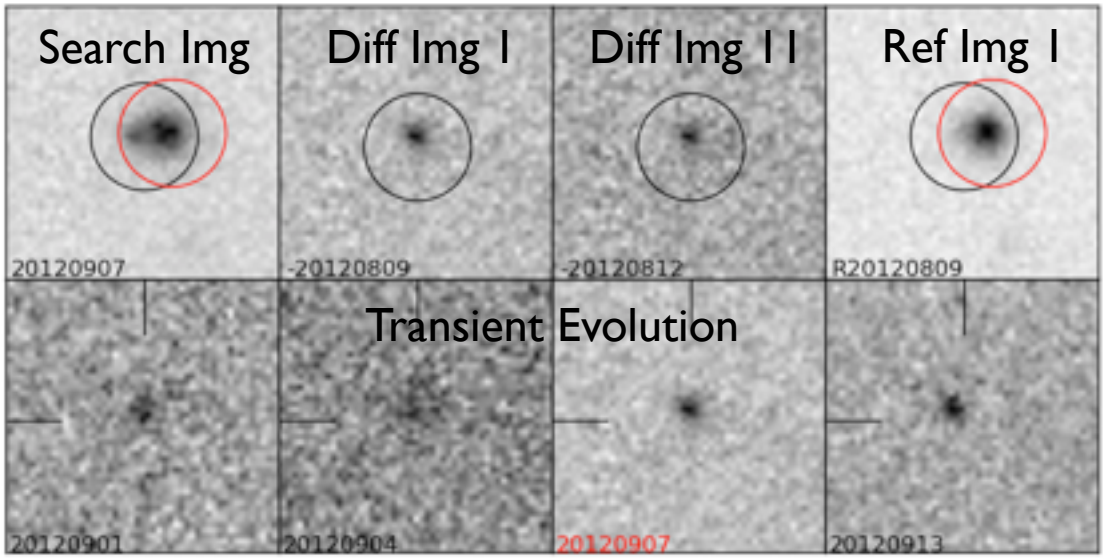
• Best ranked candidates (typically a hundred) are visually inspected

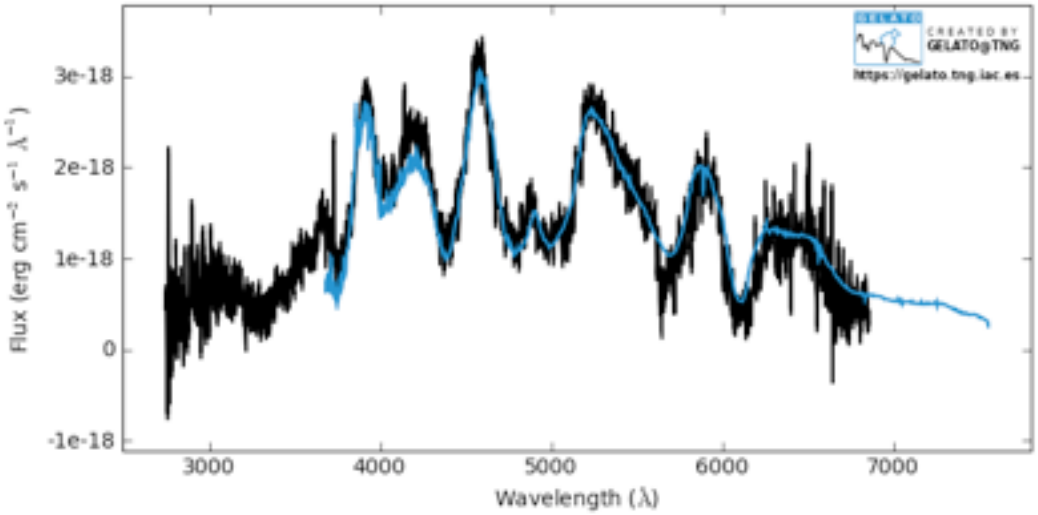
• Selected SN candidates (typically five to ten per image) are included in the follow up list

#4 RA= 3:35:16.368 DEC=-27:29:49.21 [105]

| | xc | yc | fwhm | fl rad | mag auto | mag aper | cl star |
|---|---|---|---|---|---|---|---|
| dif1 | 2551.37 | 10730.98 | 4.78 | 2.59 | 22.84 | 22.85 | 0.93 |
| dif2 | 2551.30 | 10730.99 | 4.27 | 2.27 | 23.48 | 23.39 | 0.71 |
| _ref | 2556.61 | 10731.65 | 8.07 | 3.97 | 20.69 | 20.76 | 0.02 |

d= 0.35
z= ---




Fi
S
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SN 2012ez A in

2012 UT R.A
Sep. 8.30 3:35
0".1 S

A spectrogram
UT with the ES
FORS2; range
shows the typic
supernova. Adopting a redshift z =0.348, as measured from a number of narrow lines of the host galaxy, the best fit with the GELATO tool (Harutyuyan et al. 2008, A.Ap. 488, 383) in a library of supernova spectra is with SN 1995al at fourteen days past maximum (Anupama et al. 1997, A.J. 114, 2054). The ejecta expansion velocity, derived from the position of the Si II doublet, is 11300 km/s.

le 4x2 immagini sono

dx up
sx up
immagine originale di ricerca
immagine di riferimento
up centrali: differenza fra l'immagine di ricerca e due diversi riferimenti (uno e' quello a sx, vedi data)

4 stamps bottom

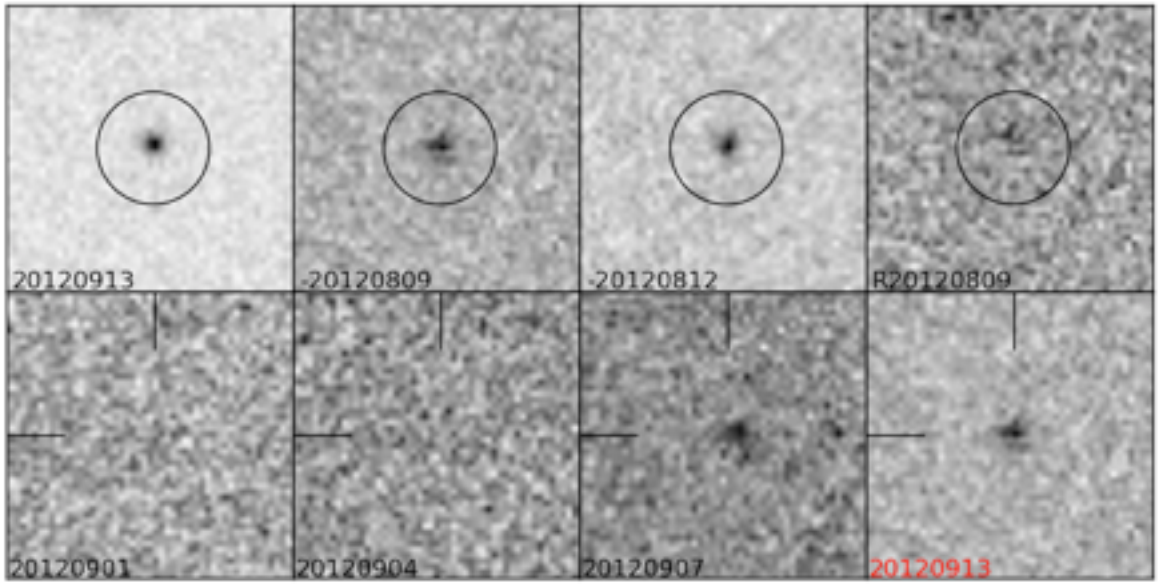
differenza fra immagini di ricerca a diverse epoche e una immagine di riferimento. ti fa vedere l'evoluzione temporale del transiente (vedi le date)

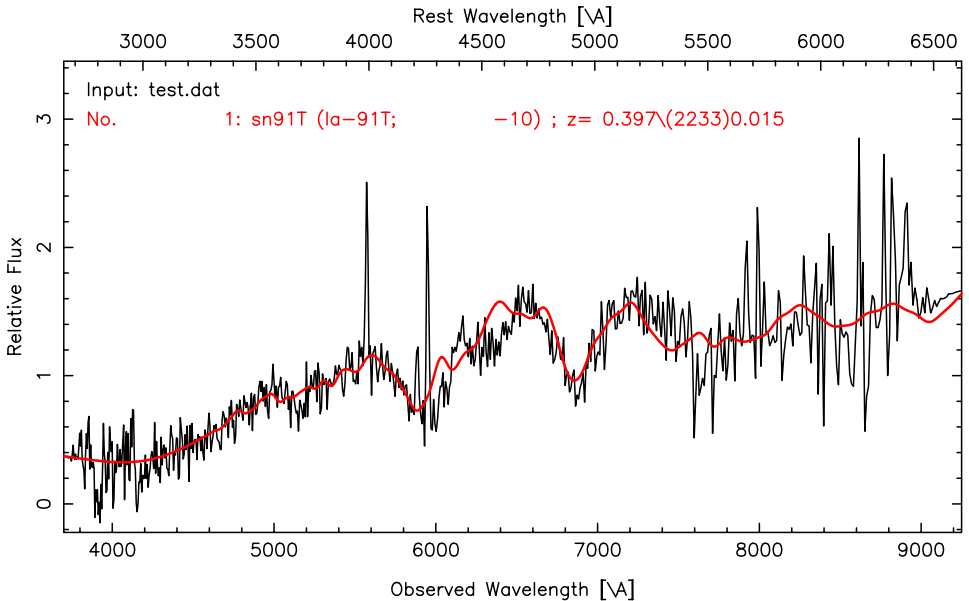
# First confirmed SN candidates (CBET 3236)

#27 RA= 3:34:59.022 DEC=-27:51:55.43 [60]

| | xc | yc | fwhm | fl rad | mag auto | aper | cl star |
|---|---|---|---|---|---|---|---|
| dif1 | 3666.64 | 4419.02 | 4.66 | 2.36 | 23.42 | 23.39 | 0.94 |
| dif2 | 3666.74 | 4419.63 | 3.92 | 1.92 | 23.55 | 23.41 | 0.96 |

d= ---
z= ---




SN 2012fa in VOICE-CDFS-1 field

| 2012 UT | R.A. | Decl. | Mag. | Offset |
|---|---|---|---|---|
| Sep. 14.24 | 3:34:59.022 | -27:51:55.43 | 23.4 | -- |

A spectrogram of 2012fa, which is located at the center of a very faint galaxy, was obtained on Sept. 15.27 (as above). Cross-correlation with a library of supernova spectra using the Supernova Identification tool (SNID; Blondin and Tonry 2007, Ap.J. 666, 1024) shows that the object is very similar to the bright type-Ia supernova 1991T at ten days before maximum (Ruiz-Lapuente et al. 1992, Ap.J. 387, L33) when placed at a redshift, z, of about 0.4. As for SN 1991T at this phase, the Si II doublet is barely visible.

VST SN Search Image Acquired Sep 14th

acquisition
*transfer to Naples*
calibration with VST-Tube
*transfer to Padova*
SN candidate detection
*web publishing*
spectroscopic observation with FORS2
SN candidate confirmation & classification

UT2 SN Candidate Confirmation Sep 15th

# VST SN Search Image Acquired Sep 14th

acquisition
*transfer to Naples*
calibration with VST-Tube
*transfer to Padova*
SN candidate detection
*web publishing*
spectroscopic observation with FORS2
SN candidate confirmation & classification

# UT2 SN Candidate Confirmation Sep 15th

| | |
|---|---|
| Data calibration (VST-Tube) | Grado, Limatola, Capaccioli |
| SN Search tools | Cappellaro, Botticella, Pignata |
| Galaxy characterisation | Vaccari, Covone, Paolillo, Marchetti |
| Transient characterisation | Benetti, Pastorello, Tomasella, Turatto |

# Vst Optical Imaging of the Cdfs & Es1

**Survey Specs:**

VST ugri Optical Survey of the CDFS & ES1 Fields (4 + 4 $deg^2$) to $m_{AB}$~26

**Extant & Future Ancillary Data:**

- GALEX (FUV & NUV)
- Spitzer IRAC & MIPS 3.6-160 micron 7-band (SWIRE)
- NIR (VISTA-VIDEO ZYJHK)
- MIR (Spitzer-SERVS IRAC 3.6 and 4.5 micron)
- FIR/SMM (Herschel-HerMES 100/160/250/350/500 micron)
- ATCA (ATLAS) 1.4 GHz Medium-Deep Radio Continuum
- MeerKAT (MIGHTEE) 1.4 GHz Ultra-Deep Radio Continuum
- PRIMUS/CSI Optically/Spitzer-Selected Spectroscopic Follow-Up
- Photometric redshifts available on smaller areas (0.25 $deg^2$, Cardamone+ 2010) and/or based on shallower data ($m_{AB}$~24, Rowan-Robinson+ 2012)

# VOICE Science Rationale

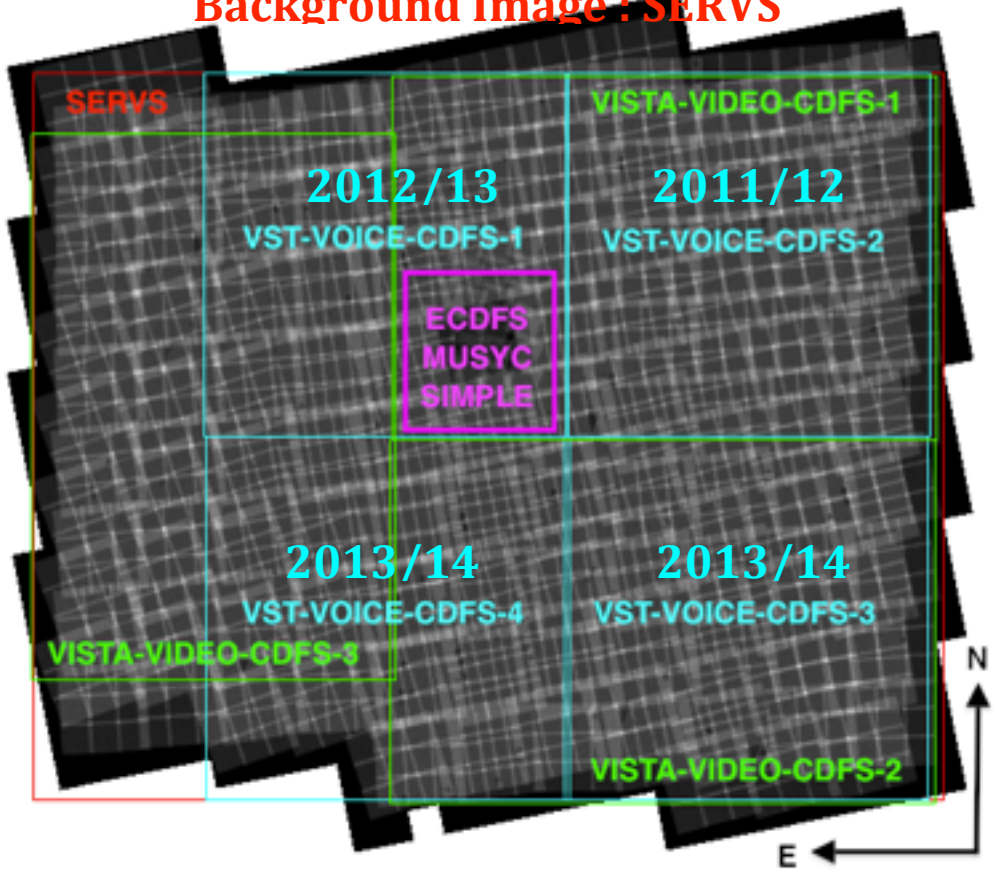
## Science Goals

z<0.5
- morphological mix as a function of
  - stellar mass
  - star formation rate
  - local environment
- constrain the mass assembly history of galaxies and their star formation rates

z~0.5
weak lensing to detect massive clusters ($10^{14}$ $M_{sun}$) and determine 2D total mass distribution

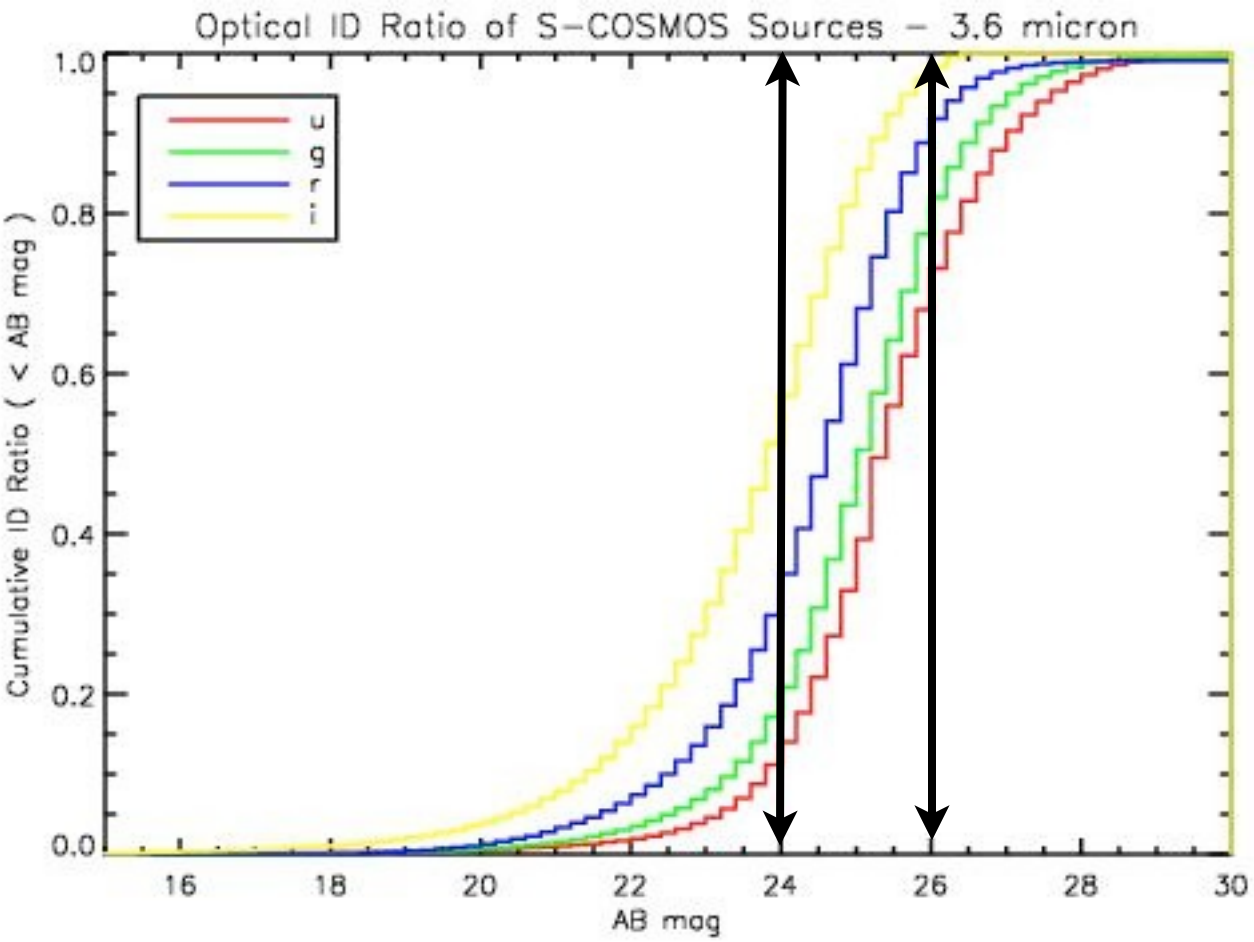
z>0.5
(combined with NIR/MIR/FIR/SMM/Radio) large sample of ~M* galaxies enabling studies of cosmic star formation history

Background Image : SERVS




NB : Most survey science only kicking in close to survey completion

# Spitzer Optical IDs




**Multi-Band Deeper Ancillary Data (Moving from 24 to 26 in AB) are key to detect the bulk of the Spitzer population (and search for high-z dropouts)**

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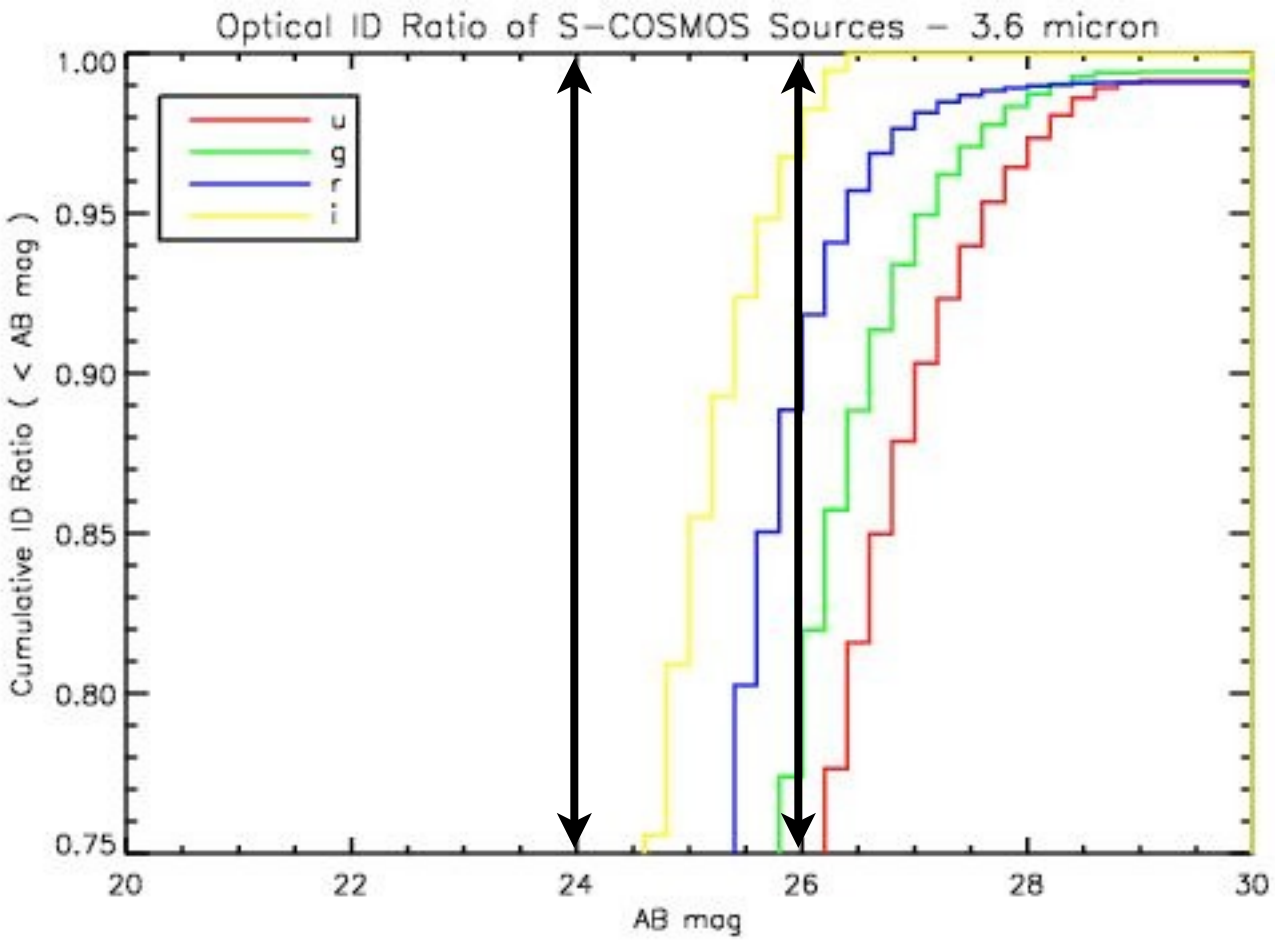
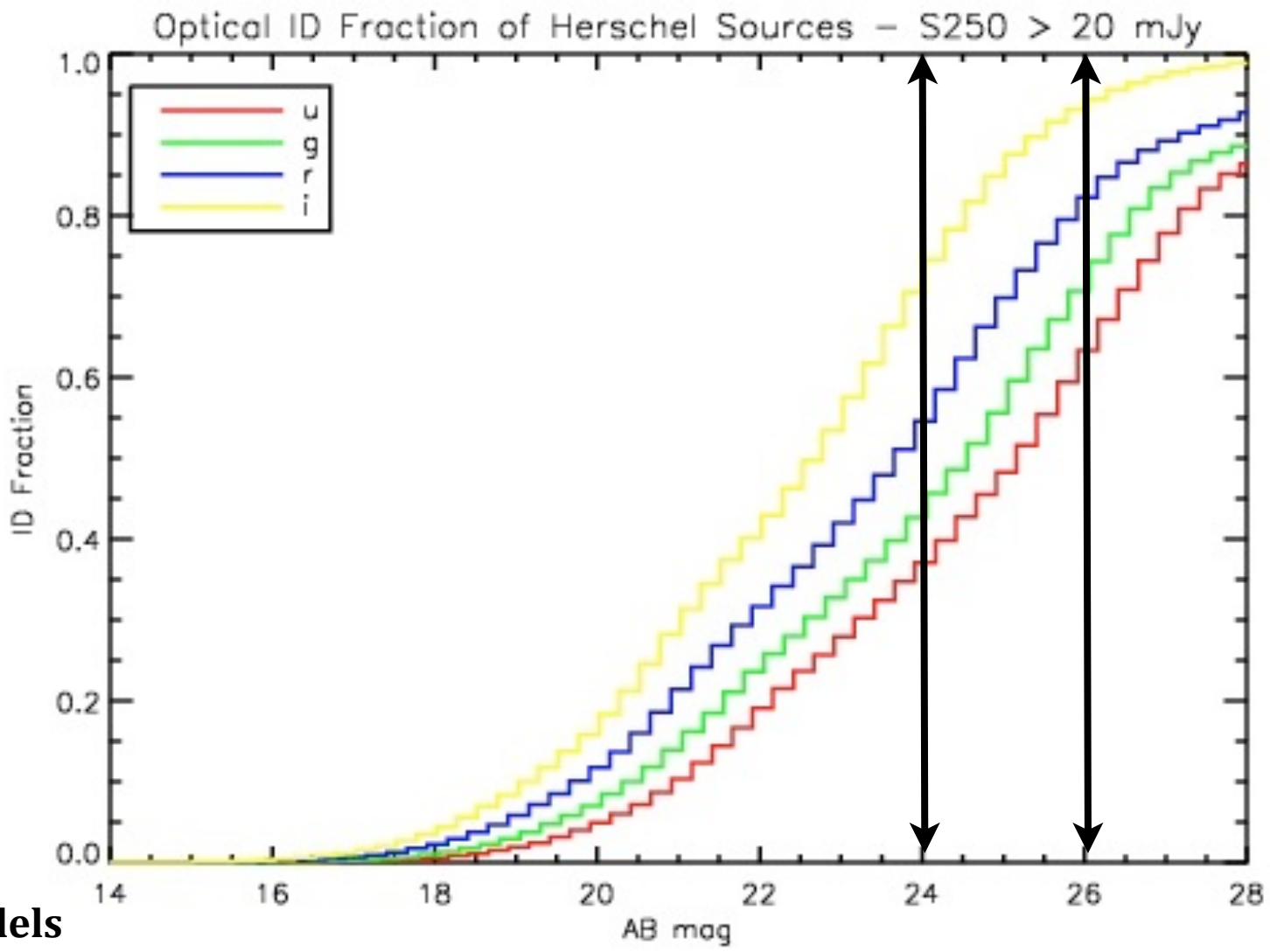



**Multi-Band Deeper Ancillary Data (Moving from 24 to 26 in AB) are key to detect the bulk of the Spitzer population (and search for high-z dropouts)**

# Herschel Optical IDs

**Detect Herschel Sources Down To Herschel Confusion Limit**




**Based on Xu's Models**

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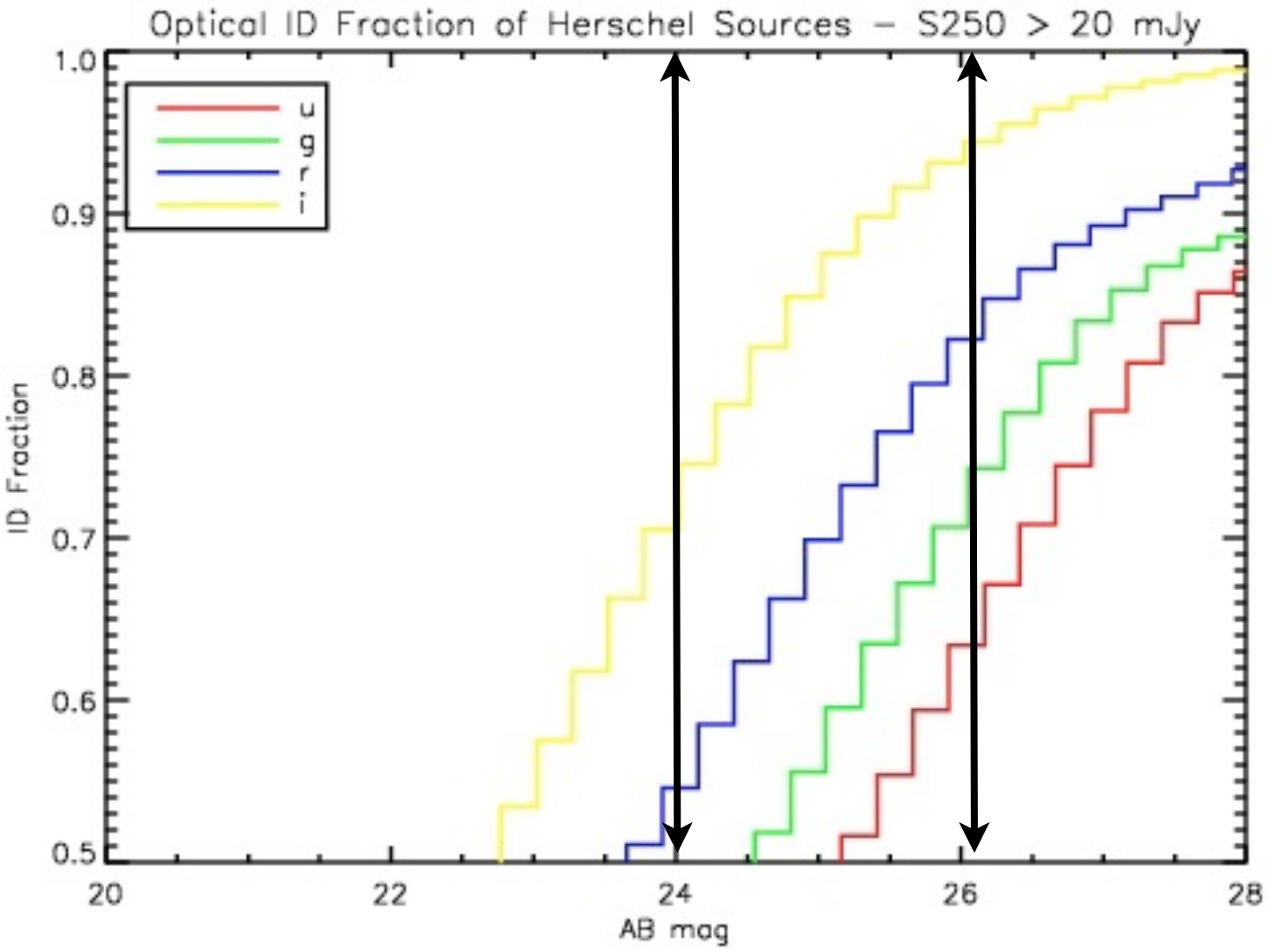
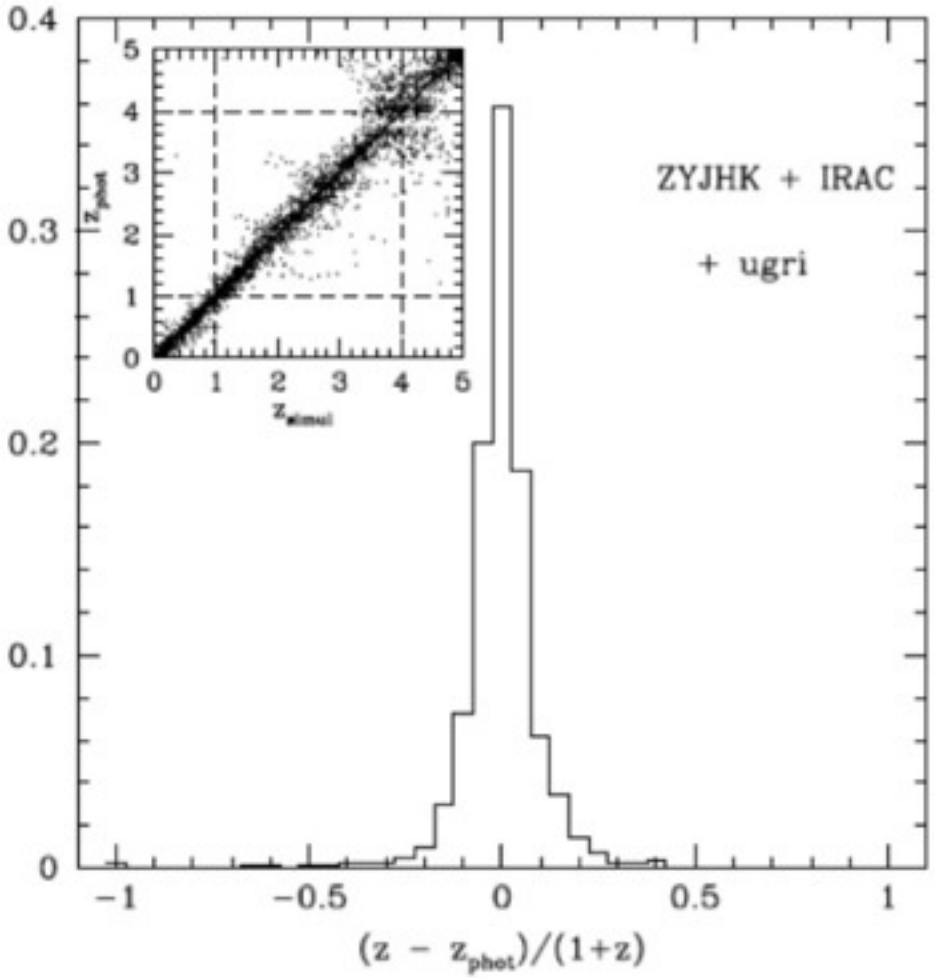
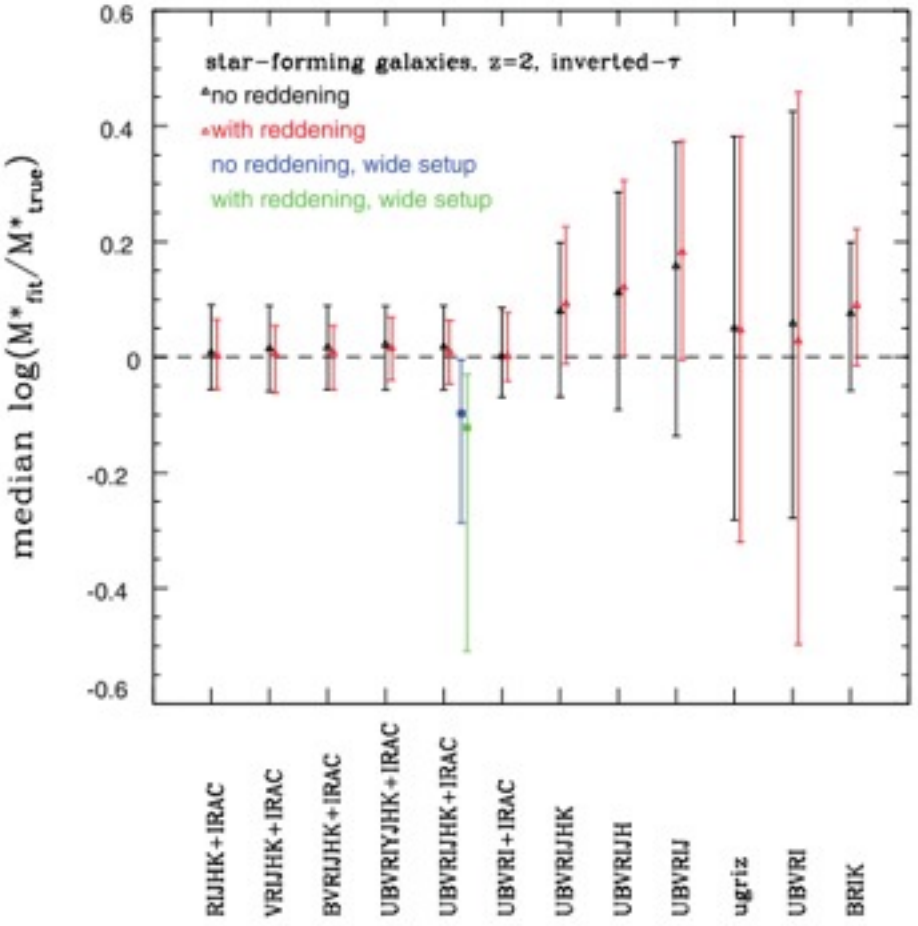



**Based on Xu's M**

# Phot-z's & Stellar Masses



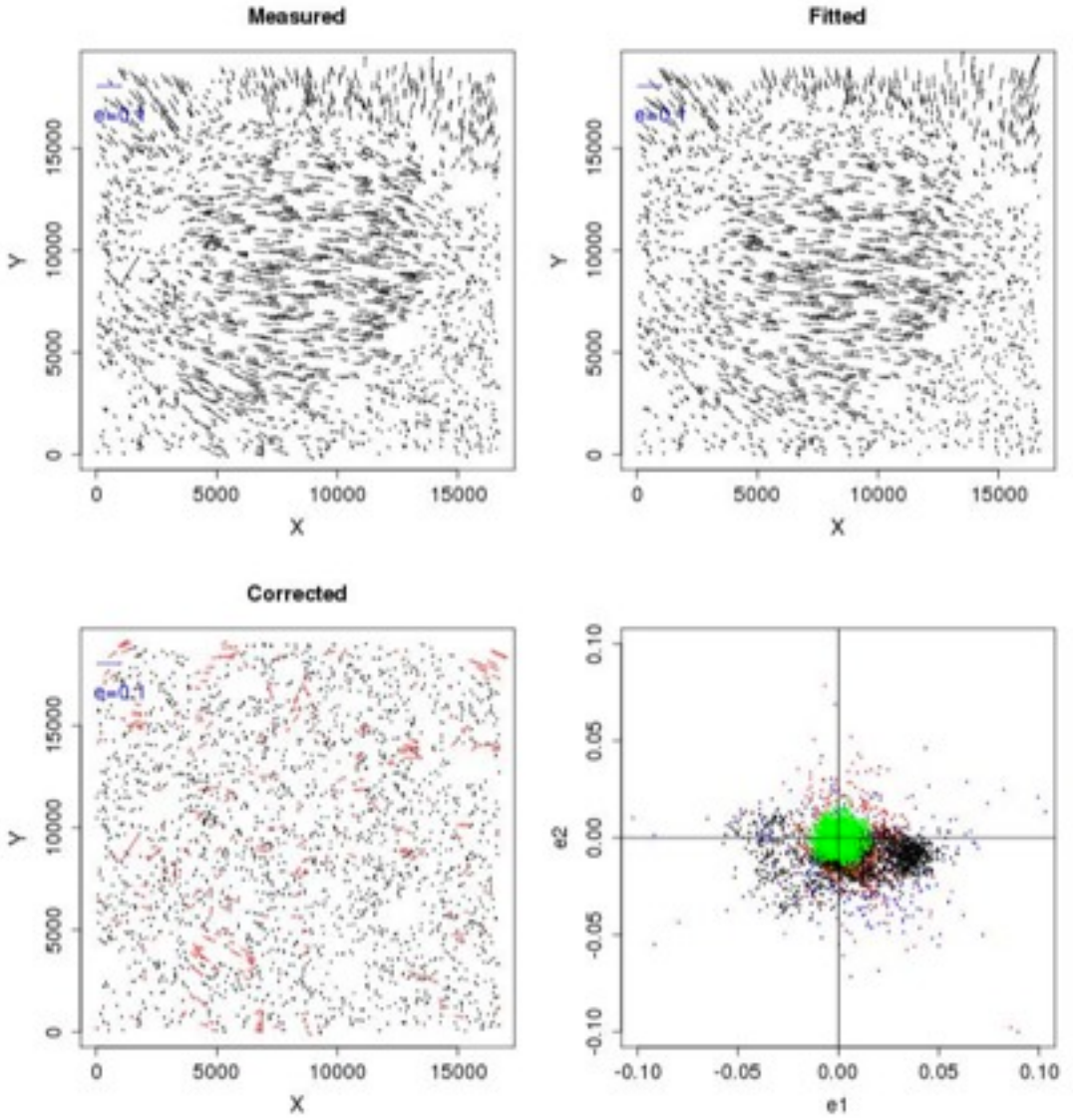

**Simulations by Janine Pforr et al. 2012 using Maraston Models**

# VST COSMOS Field
# Weak Lensing Analysis
# (Giovanni Covone & Corinne Tamburis)

r-band imaging
57 frames (360s) with average seeing <0.8”

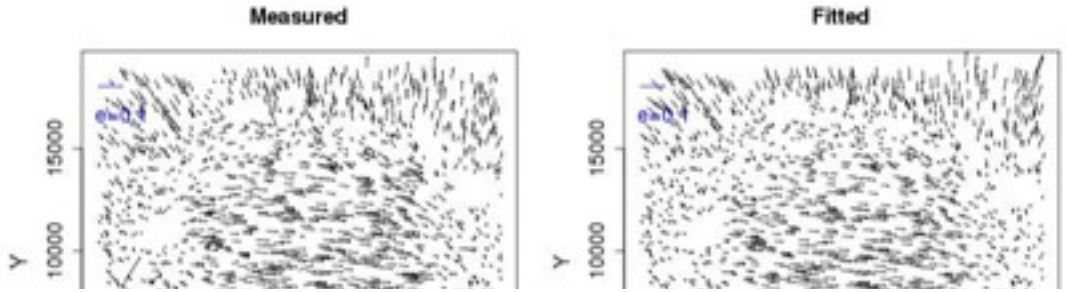
*Goal : compare weak lensing analysis with a complete census of galaxy clusters (from COSMOS collaboration)*

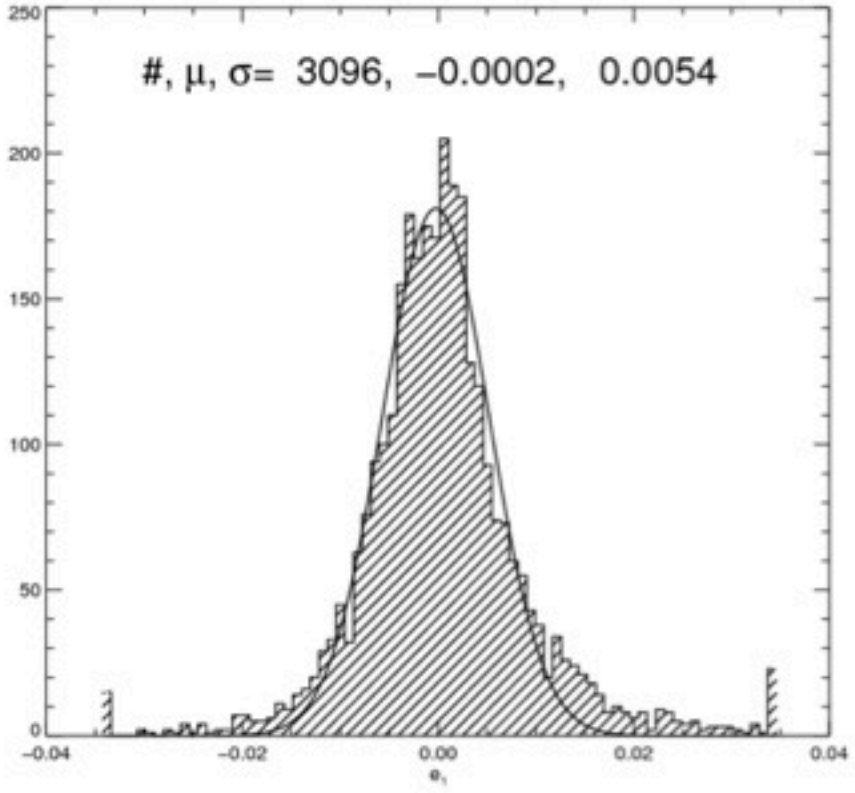
# VST COSMOS Field
# Correcting PSF Anisotropy

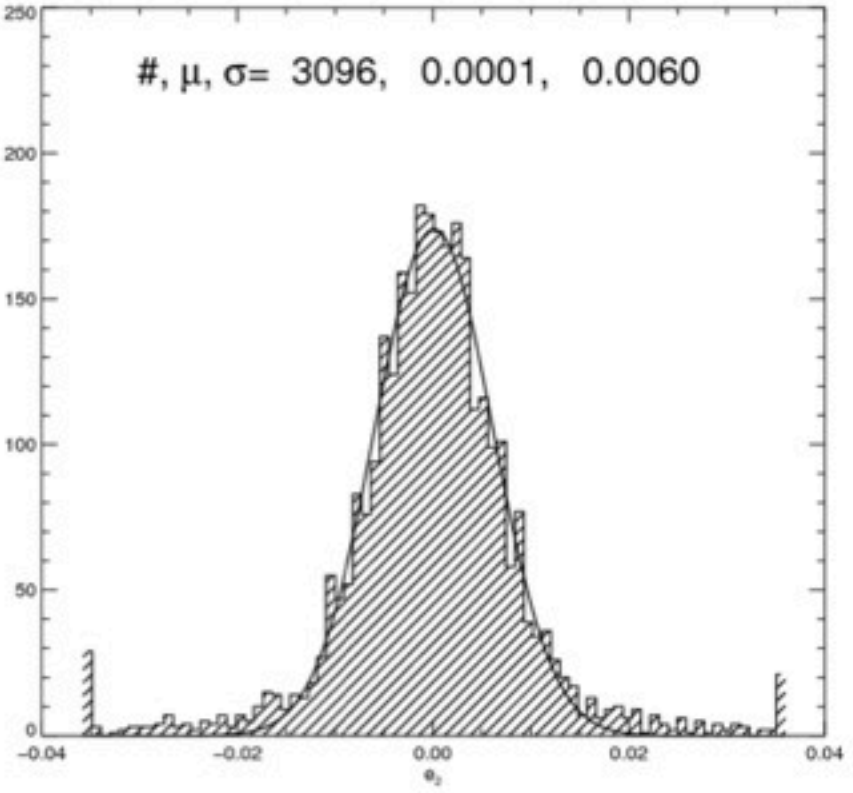



Black : Stars Before Corr
Green : Stars After Corr
Red : Excluded Stars

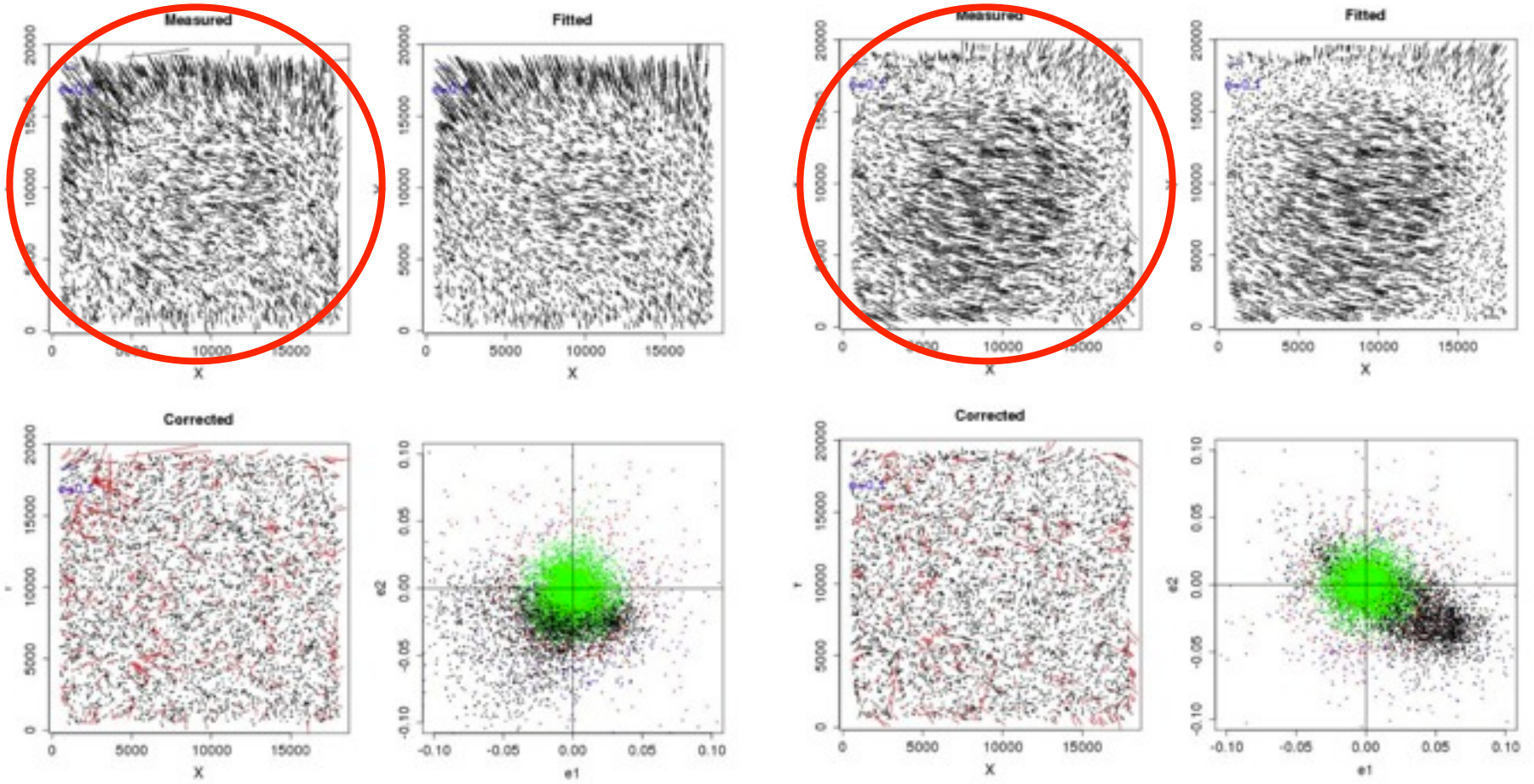
# VST COSMOS Field
# Correcting PSF Anisotropy



# Strong Variation of PSF Pattern with Epoch

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What's Next? Single epoch PSF anisotropy correction!

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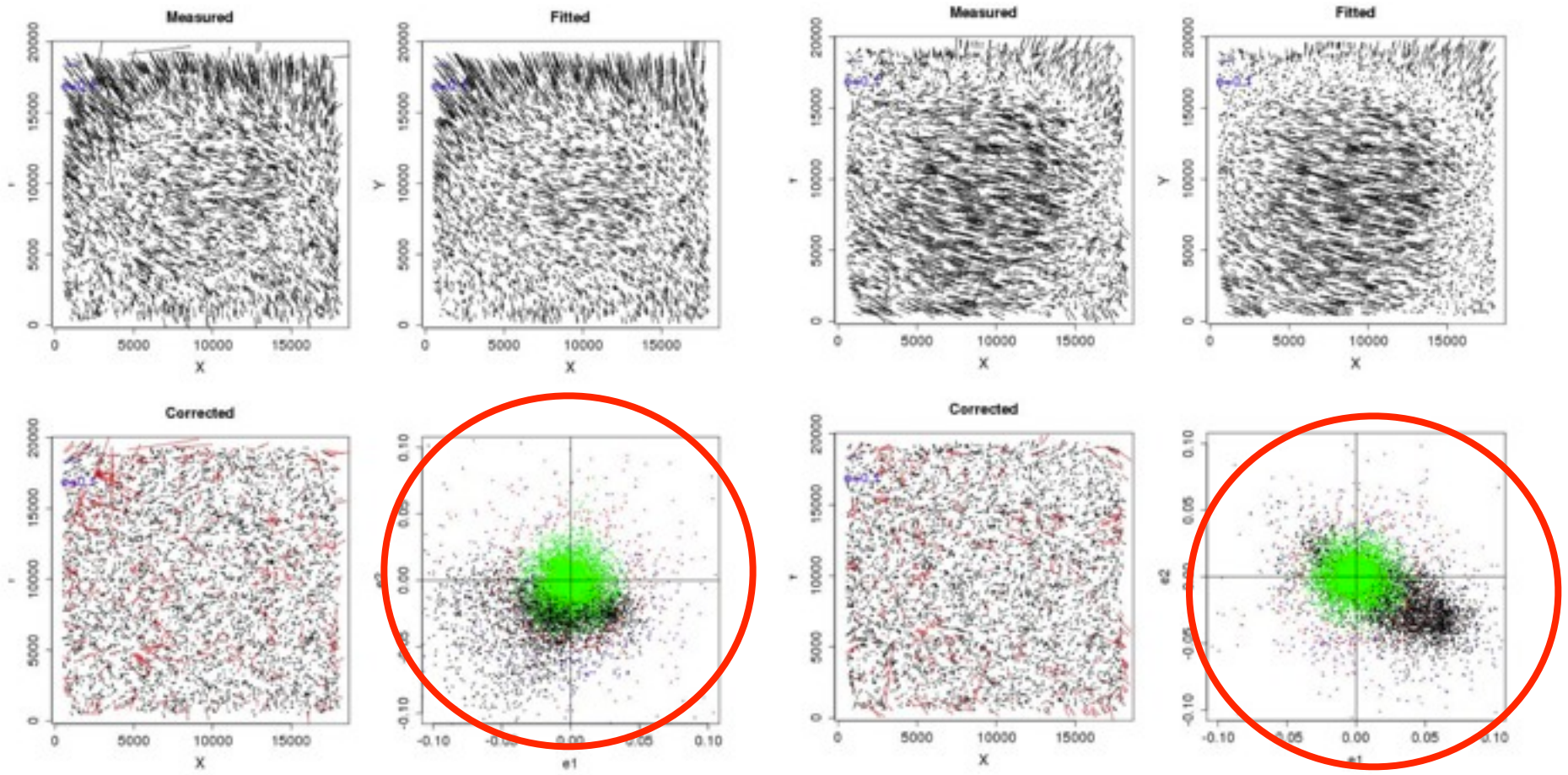


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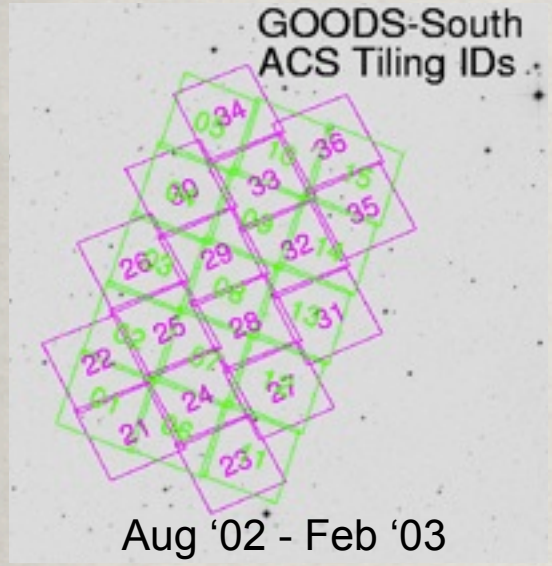
What's Next? Single epoch PSF anisotropy correction!

# AGN variability Studies

- Variability selected AGNs are useful where there is poor/no X-ray coverage
- Different selection function w.r.t. other techniques: photometry/spectroscopy/x-rays
  - Useful for X-ray faint, possibly obscured AGNs (peculiar dust to gas ratio?)
  - Identifies AGNs also when the host galaxy contribution is large
- Allows to discover dormant BHs : tidal disruption events

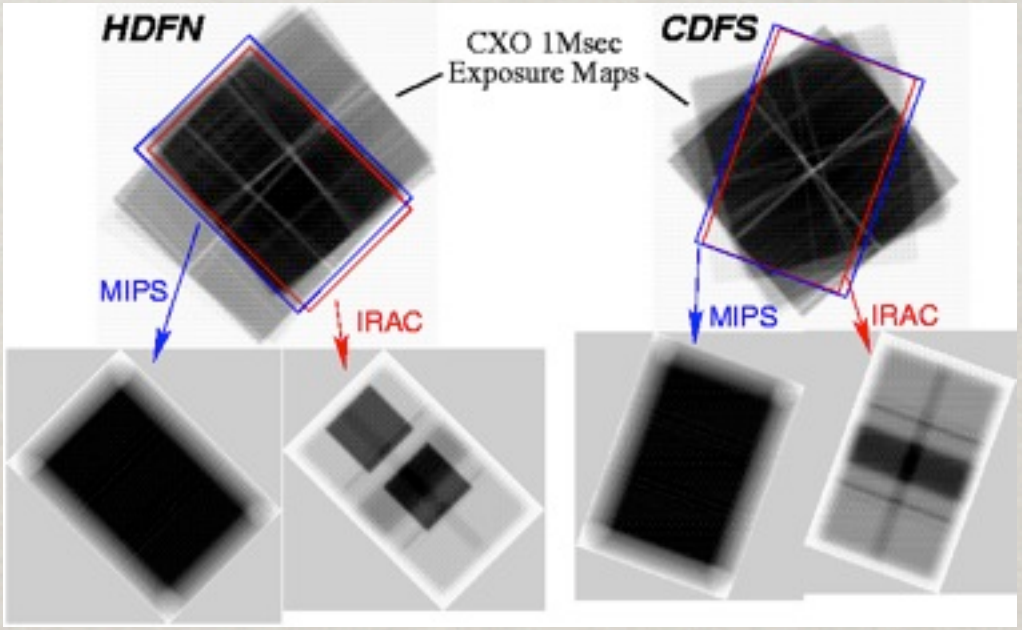
# GOODS/ACS Layout and Cadence





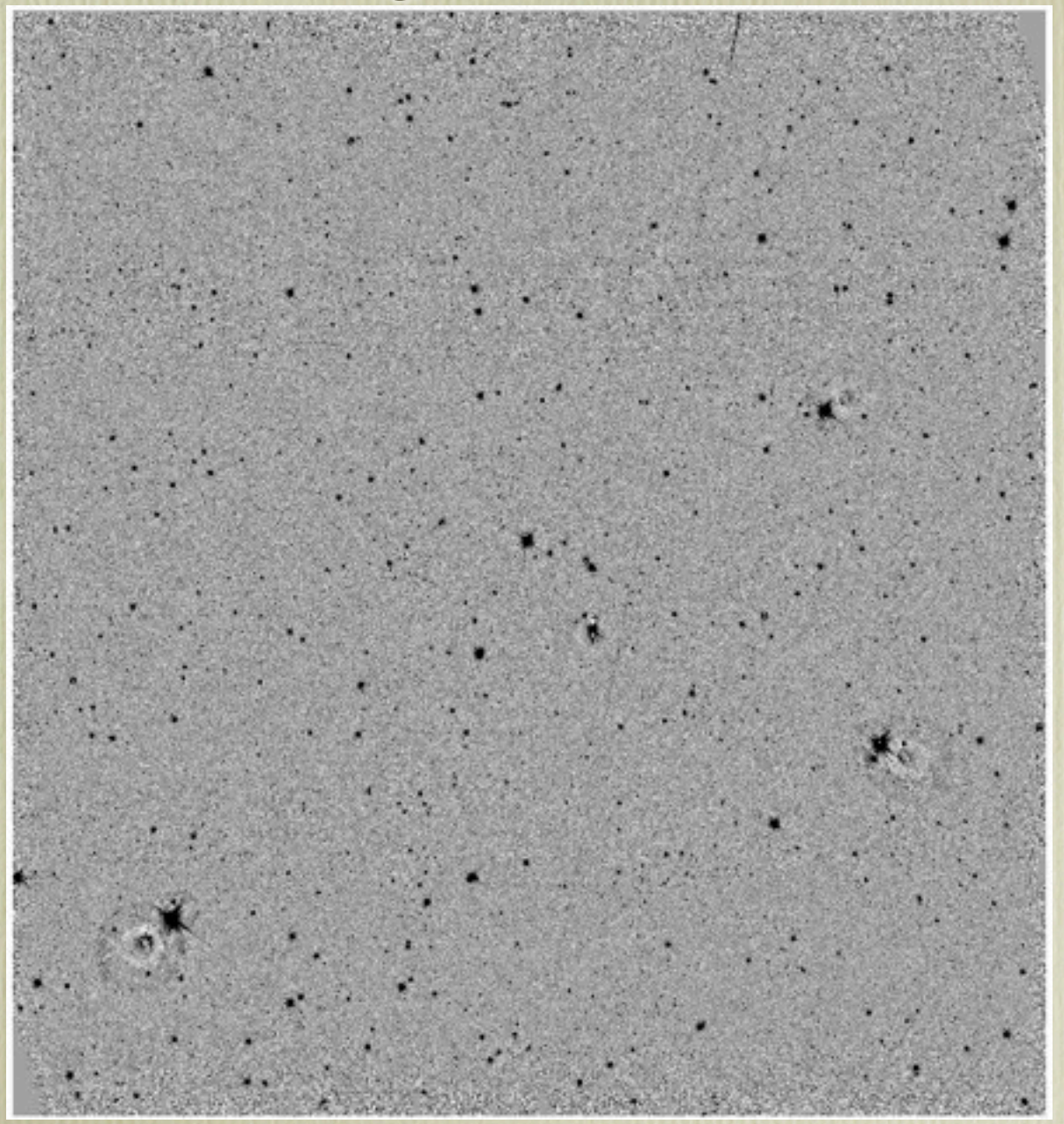
5 epochs/field, spaced by 45 days
V,i,z @ 0.5/0.5/1.0 orbits/epoch

Four new GOODS-N "i+z" epochs in Cycle 12 ('03-'04)
Four new N+S "i+z" epochs in Cycle 13 ('04-'05)



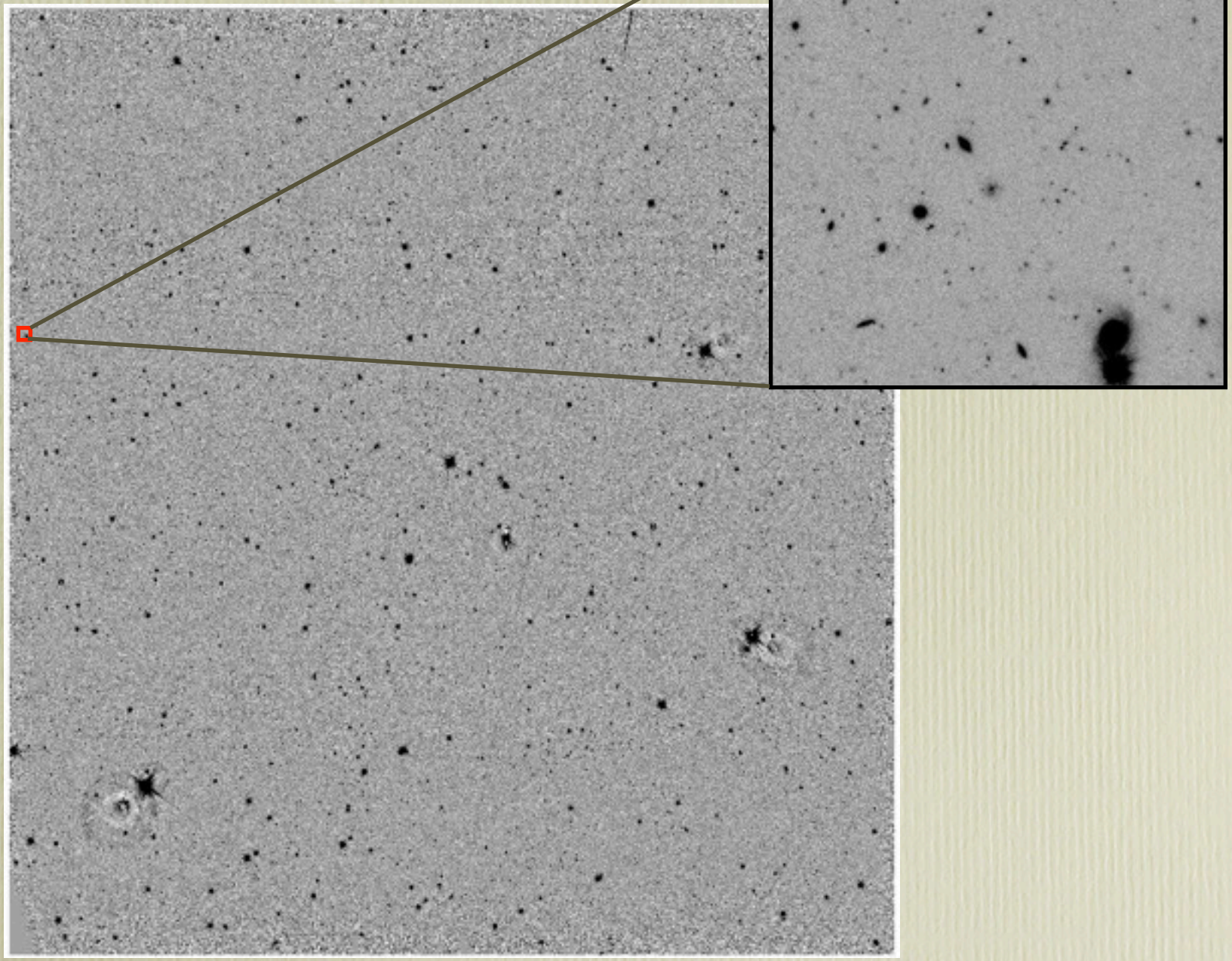

Maurizio Paolillo

# VST + OmegaCAM



1 deg - 16384 pix

# VST + OmegaCAM



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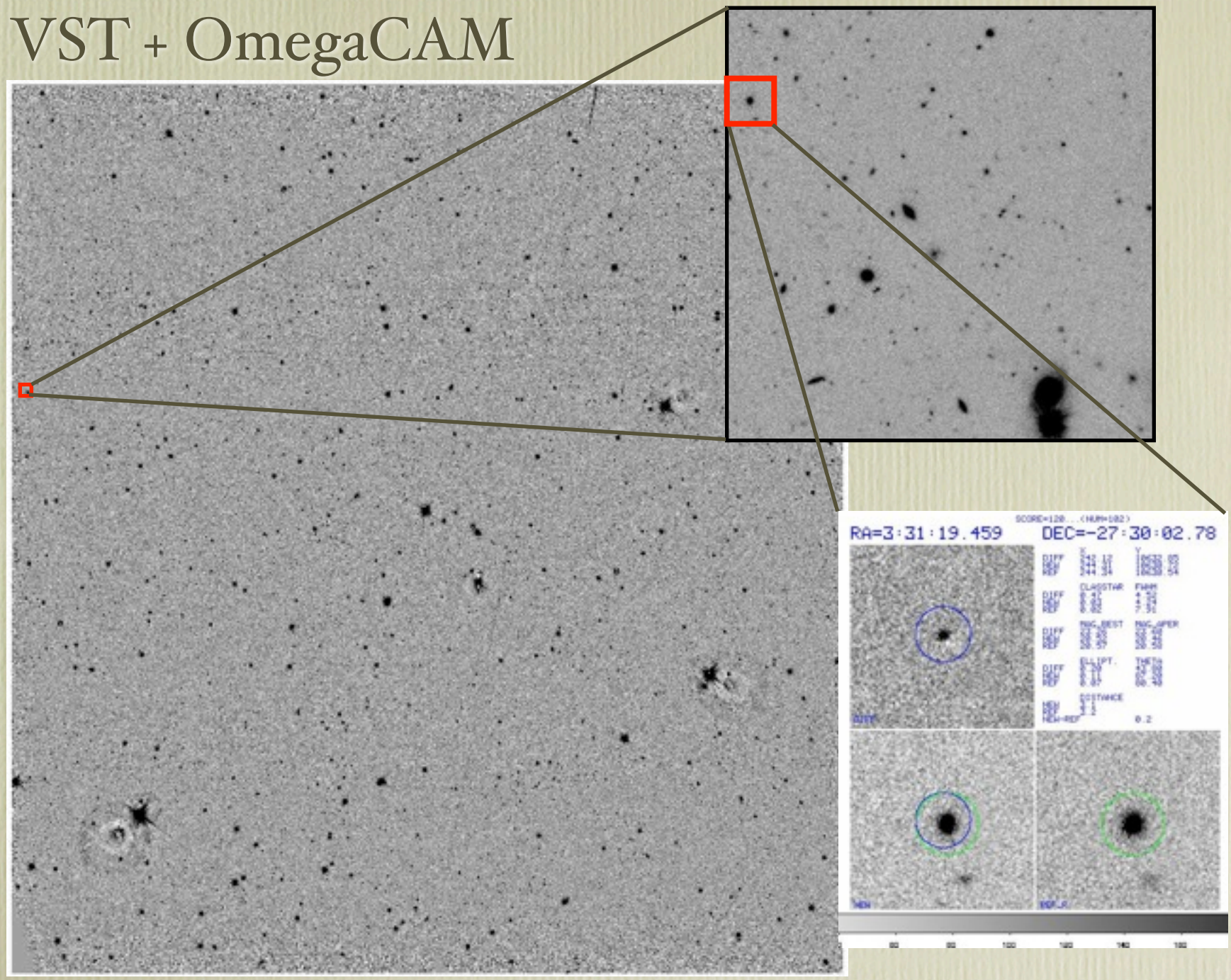
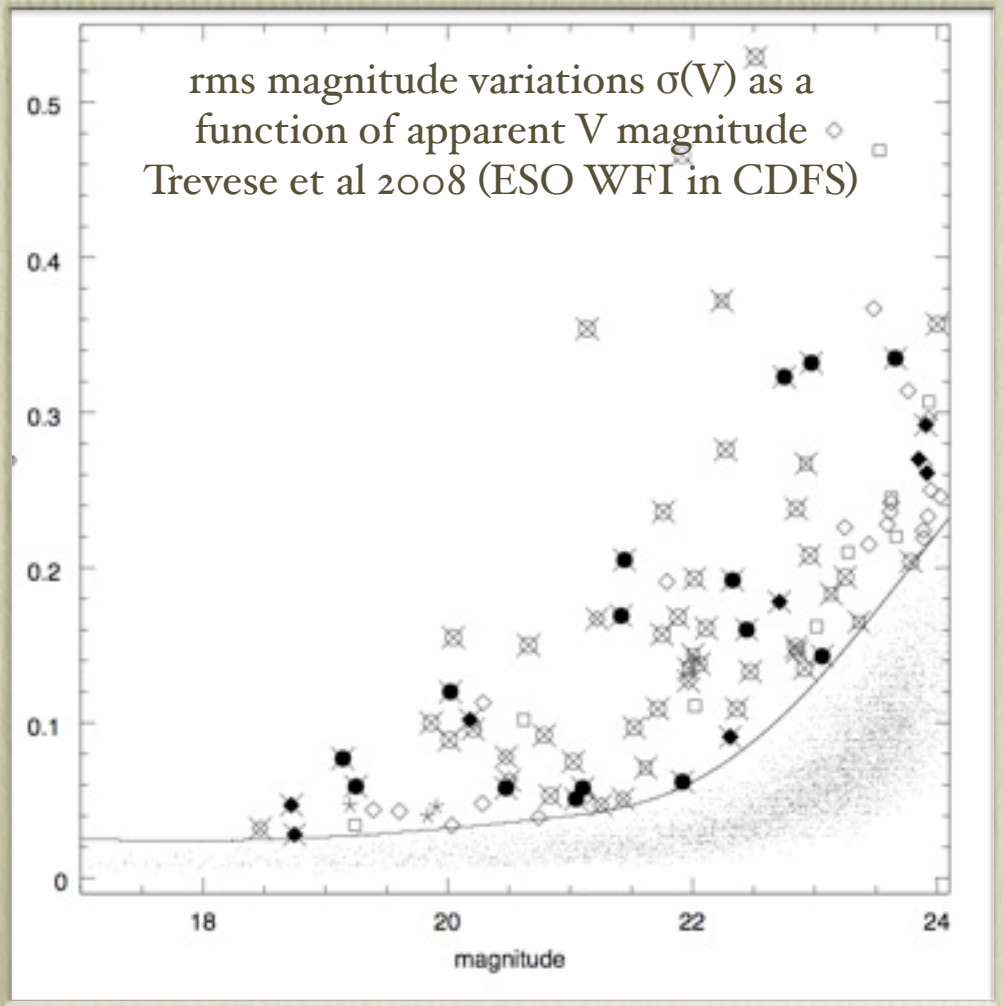
# VST + OmegaCAM

1 deg - 16384 pix



# Catalog Search for AGN Variability



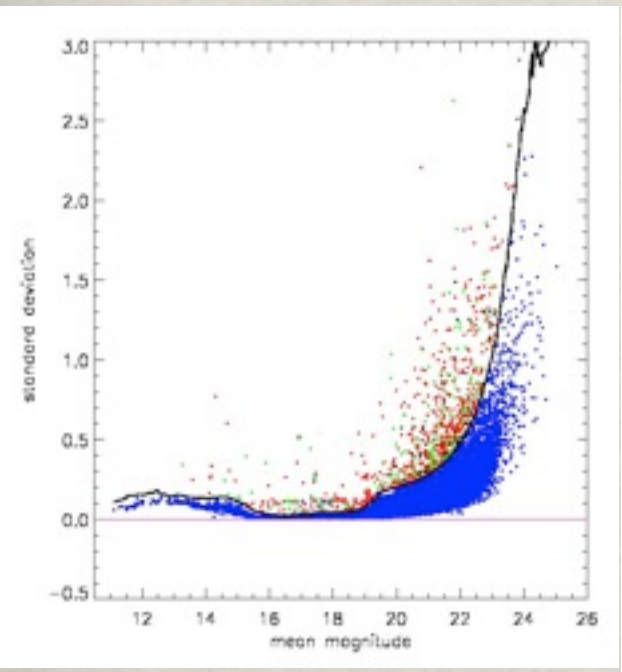

$$\overline{m}_k = \frac{1}{N_{epo}} \sum_i^{N_{epo}} m_k^i$$

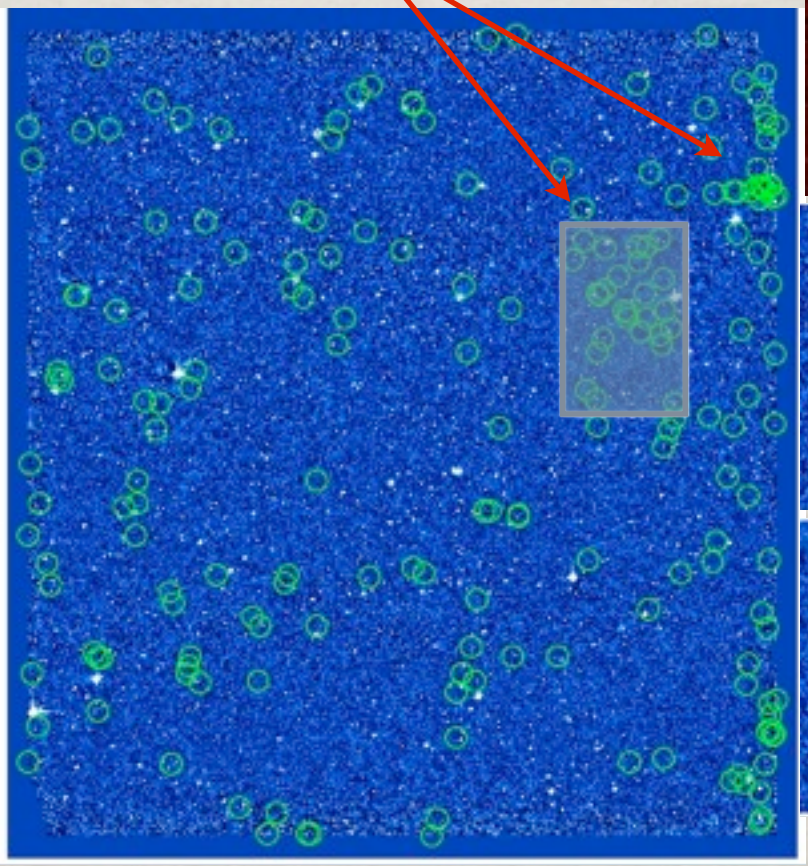
$$\sigma_k = [\frac{1}{N_{epo}} \sum_i^{N_{epo}} (m_k^i - \overline{m}_k)^2]$$

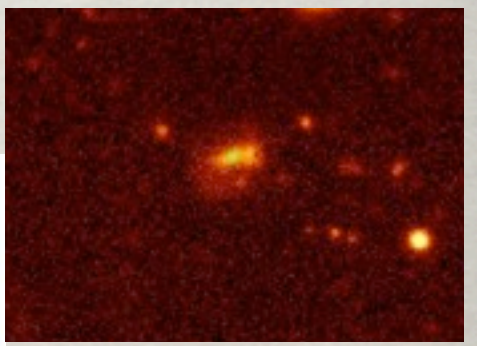
# Preliminary results variable sources in the COSMOS field (Maurizio Paolillo & Demetra De Cicco)

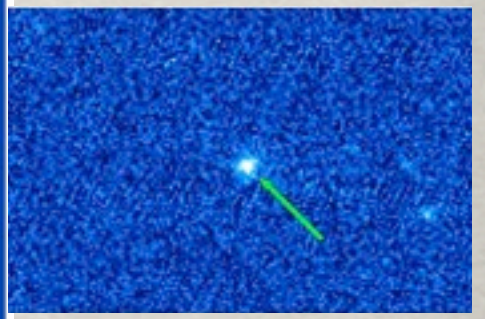
Still contaminants to remove near edges and problematic CCDs

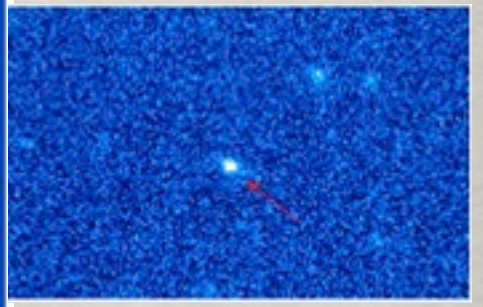
Candidates









Multi-Wavelength Analysis Ongoing

Maurizio Paolillo

# To Be Continued...

# The VST GT SUDARE/VOICE Survey

# The Deaths of Stars & The Lives of Galaxies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**SUDARE : Under Construction at http://graspa.oapd.inaf.it/**
**VOICE : http://people.na.infn.it/~covone/voice/voice.html**

**Enrico Cappellaro, Giovanni Covone, Giuliano Pignata, Maria Teresa Botticella**
**Lino Grado, Luca Limatola, Lucia Marchetti, Maurizio Paolillo, Mario Radovich**
**Massimo Capaccioli, Alberto Franceschini, Nicola Napolitano**